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PRINCIPLES OF CENTRAL-ENERGY SYSTEMS
CENTRAL-ENERGY SYSTEMS
CENTRAL-ENERGY MAIN AND BRANCH EXCHANGES
COMMON-BATTERY SIGNALING SYSTEMS
BELL CENTRAL-ENERGY SYSTEM
BELL TRUNK CIRCUITS
BELL TOLL AND TESTING CIRCUITS
KELLOGG CENTRAL-ENERGY SYSTEM
PARTY-LINE SYSTEMS
EXCHANGE WIRING AND EXTENSION TELEPHONES
SIMULTANEOUS TELEPHONY AND TELEGRAPHY
STORAGE BATTERIES

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools, is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one, or to rise to a higher level in the one he now pursues. Furthermore, he wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the

indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one select the proper formula, method, or process and in teaching him how and when it should be used.

In this volume the principles underlying practically all central-energy, or common-battery, telephone systems have been clearly explained, diagrams of connections and the operation of nearly all independent and Bell central-energy systems are described. Central-energy main and branch exchanges and common-battery signaling telephone systems are also fully considered. Then follows an excellent treatment of trunk, toll, and testing circuits; party-line systems; exchange wiring; and extension telephones. To meet the demand for sending both telephone and telegraph messages over the same circuits at the same time, a number of so-called simplex and composite telephone and telegraph systems have been developed and are fully illustrated and described in this volume. Finally, storage batteries and their care and use in telephone exchanges have been very fully considered. The utmost care has been taken to treat all the subjects in a manner most useful to those engaged in telephone exchanges and manufacturing companies.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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PRINCIPLES OF CENTRAL-ENERGY SYSTEMS

PRINCIPLE INVOLVED IN EXCHANGE AND SUBSCRIBER'S CIRCUITS

METHODS FOR SUPPLYING LINE CIRCUITS WITH CURRENT

1. The idea of replacing all the transmitter batteries and the signaling generators at the subscribers' stations by a single source of current located at the central station has proved so successful that most of the new large exchanges are now operated on this plan. They are called **central-energy,** or **common-battery, systems** because all the electrical energy is supplied from the central exchange. The problem of doing this, however, was not an easy one to solve, for, although it had been occupying the minds of telephone engineers almost since the inception of the telephone, no thoroughly practical system was produced until about 1892.

BATTERY IN SERIES IN LINE CIRCUIT

2. The most obvious and earliest solution of the problem was to do away with the induction coil at the subscribers' stations, placing the transmitter and receiver at each station in series in the line wire, the talking battery being placed at the central office in series in the circuit formed by the two connected lines. This arrangement would require a separate battery for each pair of cords and plugs, and the transmitter

at one station would have to vary the resistance of the entire circuit in order to cause corresponding variations in the current flowing through the two receivers, which were connected directly in the same circuit. This system, however, is little used, for articulate speech may be transmitted in a more satisfactory manner by other arrangements of the subscribers' instruments and the arrangement having a battery in each cord circuit at the exchange was never used much because it required too many separate batteries in exchange systems.

3. The attempt has been made to use one common battery for all the pairs of plugs, by making the tip strands of the plugs continuous from the tip of the answering to the tip of the calling plug, and by terminating all the sleeve strands in the terminals of the common talking battery, as shown in Fig. 1, in which P, P, P refer to answering plugs,

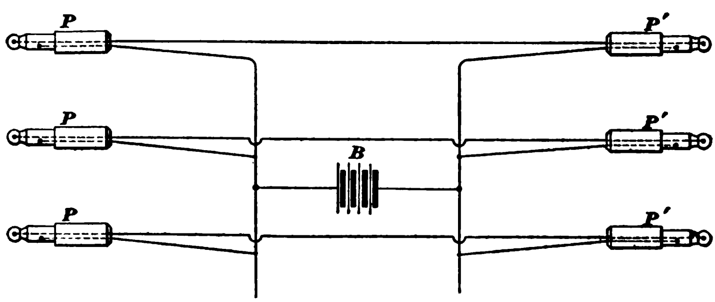


FIG. 1

P', P', P' to calling plugs, and B to the common battery. This arrangement involves the bunching together of all the sleeve strands of the answering and of the calling plugs in the exchange, and will produce cross-talk because the resistance of the common battery and the common leads to it cannot be made low enough, for all the circuits formed by the various pairs of connected lines at any time are in multiple with the common battery. Therefore, any variation in the current flowing through one pair of lines caused by the operation of a transmitter may find a path through the battery or through all the other lines in multiple. Unless the battery

is of very low internal resistance, enough of the undulations will be shunted by it through the other connected lines to produce perceptible cross-talk. For the reasons given, this arrangement is not practicable.

BATTERY BRIDGED ACROSS THE LINE CIRCUITS

4. The Stone System.—The principle of one of the successful systems by which a common battery is made to serve for all the transmitters of an exchange is illustrated in Figs. 2 and 3; it was devised by Mr. John S. Stone of the

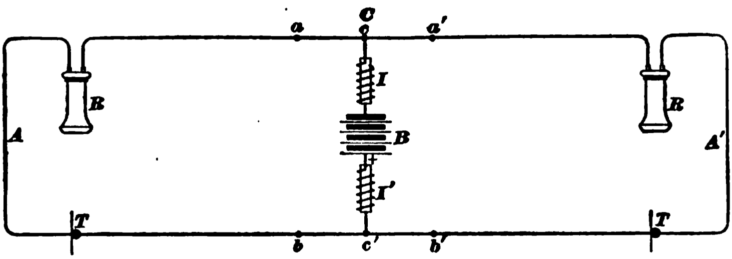


FIG. 2

Bell Company. In Fig. 2, *A* and *A'* are two subscribers' stations connected with the central office *C* by the metallic-circuit lines, as shown. The circuit of this figure illustrates the talking circuit between the two subscribers when they are connected at the central office by the cord circuits, the receivers *R* of each station being removed from the hook. The portion of the circuit included between *a* and *a'* may be considered as the tip strand of the cord circuit, and that portion between the points *b* and *b'* as the sleeve strand. The two metallic-circuit lines form, when thus connected, one continuous circuit, including the subscriber's receivers *R* and the transmitters *T* connected in series. Bridged across this circuit at the central office is a battery *B* connected between two impedance coils *I*, *I'*. The current from the positive pole of this battery will flow through the impedance coil *I'* to a point *c'*, where it will divide and pass to each of the subscriber's lines, and having passed through the instruments at each station, return to the point *c* where the two portions of

the current unite and pass through the impedance coil *I* to the negative pole of the battery. The impedance coils are made of rather coarse copper wire wound about heavy iron cores, so that, while their ohmic resistance is very low, their impedance is very high. From this, it follows that they will allow steady currents to pass through them with comparative ease, but will form a practical barrier to rapidly varying currents—such as are produced when telephoning. While the instruments at the subscribers' stations are connected with each other in series, it is clear that the two subscribers' lines are connected in multiple with respect to the battery *B* and the impedance coils *I*, *I'*. Assuming that the resistance of the two lines is the same, equal portions of current will pass through each subscriber's station. If, however, the transmitter *T* at station *A* is so operated as to increase the resistance of the line through that station, a greater portion of the current from the battery *B* will be forced through the line of station *A'*. This is true, because the impedance coils placed in the bridged circuit with the battery tend to prevent any fluctuations in the current through them. The current flowing through the coil is therefore maintained practically constant, and an increase in resistance in one of the lines will tend to cause less current to flow through that line and more through the other. In a similar manner, if the transmitter *T* at station *A* is so operated as to decrease its resistance, the greater portion of the current will flow through the line leading to station *A*, and the smaller portion will therefore pass through the line leading to station *A'*. Whatever changes take place in the resistance of the circuit of one line wire will cause corresponding changes in the current flowing in the other line wire, and these changes in current will act on the receiver at the other station in the ordinary manner. By this arrangement, the transmitter *T* at one station has only to vary the resistance of the line wire leading from the central office at that station. For short lines, this system has been found to work admirably, as the total resistance of the line can be made very low.

5. Prevention of Cross-Talk in Stone System. The battery B, as we have seen, is connected directly across the cord circuit of a pair of plugs. The use of the impedance coils renders it possible to make a single battery B serve for a large number of cord circuits, the various leads from the points c and c' on each cord circuit being led through separate impedance coils to the terminals of the common battery. This is illustrated in Fig. 3, where two pairs of subscribers' lines are supplied by a single battery B.

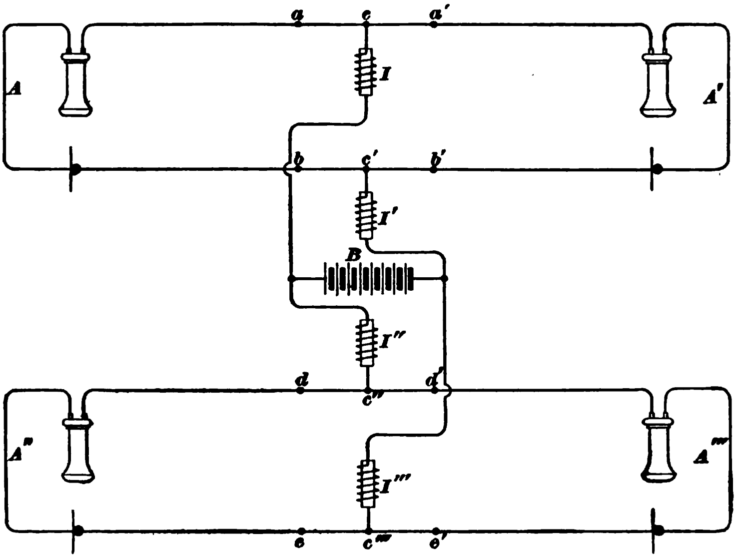


FIG. 3

The subscriber A is connected with the subscriber A' by means of the conductors a, a' and b, b' of the cord circuit. Between the points c and c' on these cord conductors is bridged a circuit containing the two impedance coils I, I' and the battery B, in exactly the same manner as is illustrated in Fig. 2. The subscribers' stations A'' and A''' are similarly connected by the conductors d, d' and e, e' of another cord circuit. Between the points c'' and c''' is bridged a circuit containing other impedance coils I'', I''' and the common battery B.

It might seem at first that this arrangement would produce cross-talk—that conversation being carried on between subscribers A and A' would also be heard on the lines A'' and A''', by virtue of the fact that the two circuits are connected together through the impedance coils. This, however, is not the case, for the impedance coils I and I' confine nearly all the fluctuations of current to the circuit of the lines leading to stations A and A'; but whatever fluctuations do find their way through the impedance coils I and I' can complete their circuits through two paths, one of which is through the battery B and the other of which is through the impedance coils I'' and I''' and the combined lines of subscribers A'' and A'''. The circuit through the impedance coils I'' and I''' contains a large amount of impedance and considerable resistance, while the circuit through the battery B contains no impedance and practically no resistance; therefore, the fluctuations in current that find their way through the impedance coils I and I' will be short-circuited by the battery B and will not pass through impedance coils I'' and I''' to the lines of subscribers A'' and A'''.

6. The chief disadvantage of the simple Stone arrangement is the fact that when two lines varying considerably in resistance are connected together through a cord circuit, the lower resistance line will take more than its share of the current from the battery; one transmitter will then have too much current and the other too little current for real good transmission. This trouble may be reduced by increasing the resistance of each coil and also the voltage of the battery, so that the longest line may still receive sufficient current for its proper operation. In this way, the resistance of any line is a smaller proportion of the total resistance of the circuit.

7. Condensers Between Answering and Calling Plugs.—Two modifications of the Stone system are extensively used by independent telephone companies. One way to reduce the disadvantage of the simple Stone system mentioned in the last article consists in connecting, as shown in Fig. 4, impedance coils u, v, w, x between each side of each

line and the battery terminals and condensers C, C' between the answering and calling sides of the cord circuit. Each line circuit is then nearly independent. Instead of depending entirely on the retarding action of one pair of coils to confine the voice currents to the proper line circuit, the electrostatic induction of a pair of condensers C, C' is employed to facilitate the transmission of the variable voice currents from one line to the other. The straight arrows represent the paths and direction of the direct current from the battery while the wavy arrows represent the path of the variable voice currents. Where both arrows are shown in the same part of a circuit, the current actually flowing is the resultant of the two currents, but practically the result is the same as though both kinds of current flowed in the circuit at the same time.

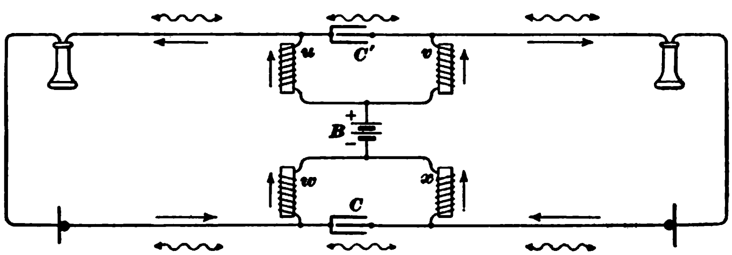


FIG. 4

By this arrangement the resistance of a pair of coils is added independently to each line circuit, which tends to make the current from the battery divide much more equally through two connected line circuits of different resistances. Moreover, the voice currents pass, by electrostatic induction, very much more readily through the condensers C, C' than through the coils u, v, w, x, which have considerable impedance.

8. Two-Battery Condenser Circuit.—The other modification, which was first used by the Kellogg Switchboard and Supply Company, is shown in Fig. 5; the new feature consists in the use of two storage batteries B, B'. The current in any line is now entirely independent of the resistance of any other line to which it may be connected. As in the preceding arrangement, the impedances of the coils u, v,

w, *x* force the variable voice currents through the condensers, while the resistance of each coil is low enough for the longest line to receive sufficient current. The condensers actually improve the transmission of voice currents, which is shown by the fact that the transmission is not so good when the condensers are short-circuited. The positive terminals of the two batteries are usually connected together and grounded, but this does not alter the principles involved.

9. In these modifications of the Stone system, the coils *u*, *v*, *w*, *x* may be separate impedance coils or separate relays associated either with each line circuit or with each cord circuit, or the two coils *u*, *w* may form two windings on the same relay core and *v*, *x* two windings on a similar relay associated either with each line or each cord circuit; but the

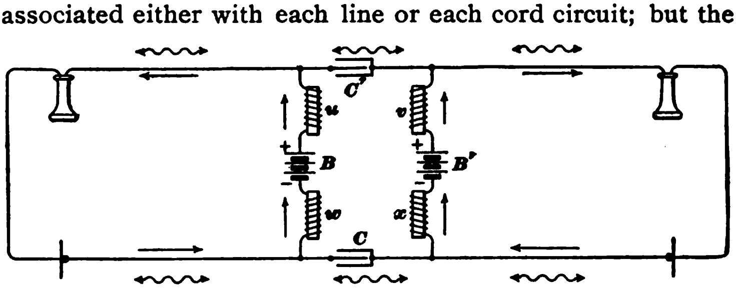


FIG. 5

condensers are always in the cord circuit. Each coil may be replaced by two coils in parallel, or both may form windings for relays, one pair of coils usually being associated with each line and one pair with each cord circuit. The resistance of each coil, or the joint resistance of two coils used in place of one coil, varies in systems of different companies from about 40 to 200 ohms.

10. The Hayes System.—A system, devised by Mr. Hammond V. Hayes for the Bell Company, is shown diagrammatically in Fig. 6, in which, as in the preceding figures, *A*, *A'* are subscribers' stations and *C* is the central office. *J*, *J'* are repeating coils, each having two equal windings *j*, *j'*. The battery is connected between one end

of each of the windings j, j' of the coil J and one end of each of the windings j, j' of the coil J'. The other terminal of each winding of the repeating coils is connected as shown, with the line wire leading to a subscriber's station. These repeating coils are merely induction coils, having their windings of equal resistance and the same number of turns. They are wound on heavy, soft-iron wire cores, and in practice the two coils J, J' are wound on the same core.

As in the preceding figures, a and a' may be considered the terminals of the tip conductor of a pair of plugs and b, b' the terminals of the sleeve conductor. Current flowing from the positive pole of the battery B will divide and pass through the separate windings j, j' of the repeating coil J to the line wires leading to stations A, A'. The two portions of the current will then proceed through the instru-

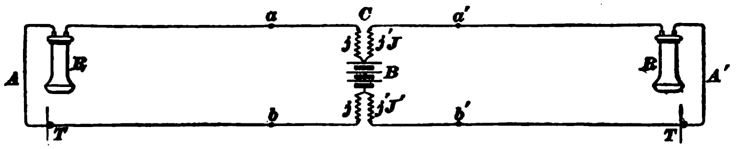


FIG. 6

ments at this station, and back to the central office through the other side of the line, and the windings j, j' of the repeating coil J' to the negative pole of the battery.

The two circuits may be considered as entirely separate, connected inductively only through the windings of the repeating coil. If a variation takes place in the transmitter at station A, the current flowing from the battery B through the circuit of that line will be correspondingly varied. These variations will pass through the windings j, j of the repeating coils, and will therefore act inductively on the windings j', j', which are in circuit with the station A'. It is easy to see that any fluctuations in current in the circuit of station A will induce similar currents in the circuit of station A', and vice versa. When station A is transmitting, the coils j, j act as primary coils and j', j' as secondary coils. When station A' is transmitting, the functions of the coils are reversed, j', j' serving as the primaries and j, j as the secondaries.

11. As in the Stone system, the battery *B* may be made to serve an unlimited number of cord circuits, a separate repeating coil being placed between the battery and each cord circuit, as shown in Fig. 7.

12. Resistance of Battery and Bus-Bars.—In the Hayes central-energy system, it is necessary to have all the main leads between the battery and the repeating coils extremely large, so as to keep down the resistance of the battery circuit, as there is greater danger of cross-talk on this kind of circuit. In some of the larger Bell systems, the main battery leads are said to be of solid copper with a cross-section of 3 square inches. Each repeating coil is individually wired to these heavy bus-bars. In other exchanges of

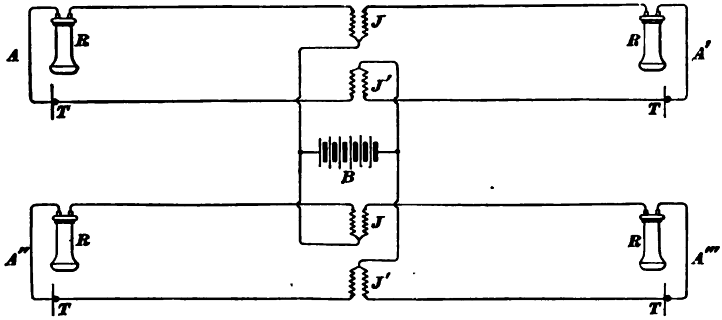


Fig. 7

equal size, but using impedance coils, the copper leads do not exceed that of a number 0000 wire.

13. One repeating coil used in the Hayes system by the Bell Company consists of 3,300 turns of wire in each of the four windings. The 40- and 20-ohm repeating coils made by the Western Electric Company and known as its No. 11 and No. 12 repeating coils are so connected that when two subscribers are talking, the current from the battery through the coil leading to one subscriber's instrument tends to neutralize the magnetic field produced by the current through the coil leading to the other subscriber's instrument, thus making the coil non-inductive "from the center out," as it is termed. The idea is to make the inductive effect of the

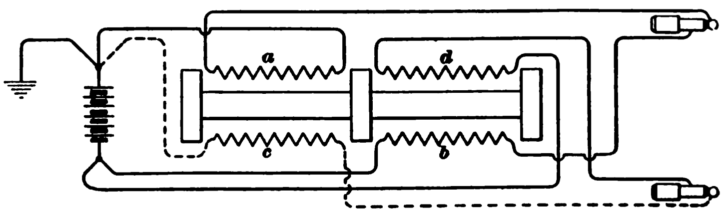
telephonic currents greater because of the lower magnetic density thus produced in the core. There is one drawback to this method, however, and that is when the windings are thus opposed to each other the impedance to outside telephonic currents is also lowered, making the tendency to cross-talk greater. In order that there may be no cross-talk between any two cord circuits, the Western Electric Company considers that the internal resistance of the battery and the leads to the bus-bars on the repeating coil rack must never exceed .1 ohm. The experience of others with these coils seems to show that a resistance of .1 ohm will give considerable cross-talk and that it is necessary, in order to avoid it, to keep this resistance below .02 or .03 ohm.

14. It is very doubtful if the magnetism approaches anywhere near saturation in any repeating coil, even where the coils are not opposed; at any rate its effect would only be noticed on very short lines, and as the transmission is good anywhere on such lines, there could not be much harm done by having them not opposed. On very long lines, the magnetism of the core would be lower and no trouble experienced. Therefore, it is probably better, as it will save copper in the battery circuit and also save the danger of cross-talk to have the windings of the repeating coil so connected that they act magnetically in the same direction. There are, however, a number of very large exchanges in this country where all the repeating coils are connected, so as to produce a neutral field, as far as possible.

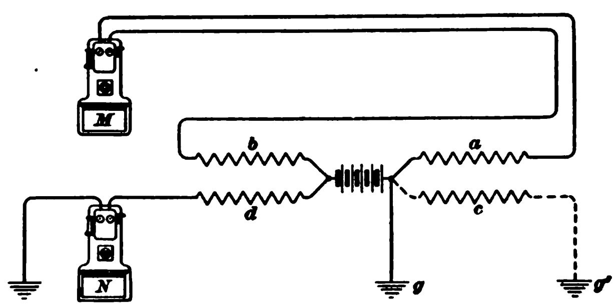
In England, where the storage batteries used seem to have considerably higher internal resistance than those used in the United States, the Western Electric Company found it necessary for the British post-office exchanges to change the connections of the repeating coils so that they were inductive from the center out, in order to get rid of cross-talk and generator noise. In this case, the resistance was probably considerably below .1 ohm. Perhaps a good rule to follow would be, that a resistance of .1 ohm for battery and leads is allowable when the repeating coils are connected

so that they are inductive from the center out, but if they are connected so that they are non-inductive from the center out, this resistance should not exceed .02 ohm.

15. Repeating coils that will operate successfully between two complete metallic circuits may not necessarily be satisfactory between complete metallic and grounded circuits. The first repeating coils used on the Hayes common-battery systems had four windings arranged on one core, as shown in Fig. 8 (*a*). When this repeating coil is used, as shown in Fig. 8 (*b*), to connect a metallic-circuit tele-



(*a*)



(*b*)

Fig. 8

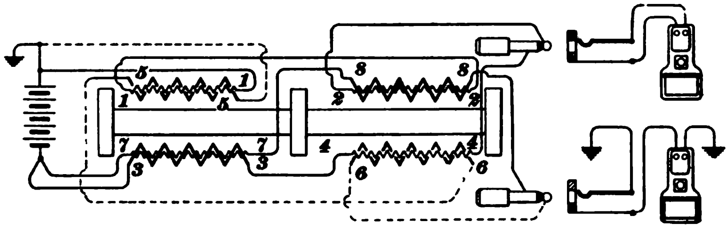
phone *M* to a grounded telephone *N*, the winding *c* is practically short-circuited by the two grounds *g*, *g*′, the ground *g* being required, or at least always used, for the busy test in multiple exchanges and for certain party-line systems. This short-circuiting of one-quarter of the repeating coil not only reduces its efficiency for talking purposes, but also unbalances the line, which may cause it to be very noisy.

For instance, if the metallic circuit line runs parallel with a trolley line or other circuit that may induce variable static charges on the two telephone wires constituting the metallic circuit, these variable charges seek the earth, one through winding *a* and the other through winding *b* and the battery. Unfortunately, both these windings do not offer equal opposition to the flow of these charges to the ground because the winding *d* has a line wire, telephone, and ground return in circuit with it, whereas the winding *c* is practically short-circuited. Such a large current, relatively, is induced in the short-circuited coil *c* that it tends to reduce the magnetism produced in the core by the primary winding *a*, thereby reducing the effective impedance of the winding *a* which, therefore, allows a larger portion of the total static charge to flow through it to ground *g*. The variable charges in *b* induce a current in *d*, but *c* being short-circuited, no current is induced in it to oppose that in *d*, hence a noise is produced in telephone *N*. Since one side of the metallic circuit has a smaller impedance than the other, the telephone *M* is not at the center of the line circuit, that is, not at the center of impedance of the circuit, hence more static electricity flows through *M* than would otherwise be the case and makes it noisy also.

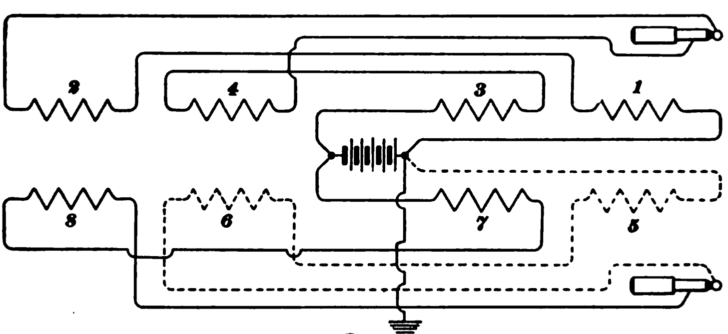
16. In order to obtain better service between grounded and complete metallic circuits, the coil shown in Fig. 9, which will preserve a static balance under about all conditions, was devised. The actual method of winding is shown at (*a*), but the balancing effect may be more readily understood by considering (*b*). It will be seen that half of the short-circuited winding *5, 6* is placed on each end of the core, consequently each half of this short-circuited winding will have an equal inductive effect on the two windings *1, 2* and *3, 4* that are in series with each side of the metallic circuit; hence, each side of the metallic circuit will offer the same opposition to the flow of static charges, consequently both telephones will be free from noise due to static charges induced in the metallic circuit by an external circuit, provided

that both sides are equal in resistance and are equally well insulated.

This eight-section coil will not work well if a ground occurs at the lightning-arrester frame, which also short-circuits the coils *1*, *2* on the tip side of the metallic circuit, because, with coils *1*, *2*, *5*, *6* short-circuited, both halves of the core are sufficiently affected to render it very inefficient as a



(a)



(b)

FIG. 9

repeating coil, whereas with the older coil, a ground on the same side of the arrester frame, which short-circuits coil *a*, Fig. 8, in addition to coil *c*, affects only the same side of the core as coil *c*, which is already short-circuited, hence the efficiency is not further affected, although the circuit is unbalanced.

BATTERY IN GROUND CIRCUIT

17. The Dean System.—A system devised by Mr. W. W. Dean for the Western Electric Company, in which current is fed to the subscribers' stations through the two sides of a metallic circuit in parallel, is shown in Fig. 10. This system also involves the use of an induction coil and an impedance coil at each subscriber's station. Across the cord circuit, the strands of which are represented by $a\,a'$ and $b\,b'$, is bridged an impedance coil I, to the center point of which is attached a wire leading to one pole of the common battery B, the other pole of which is grounded. At each subscriber's station, an impedance coil I' is bridged across

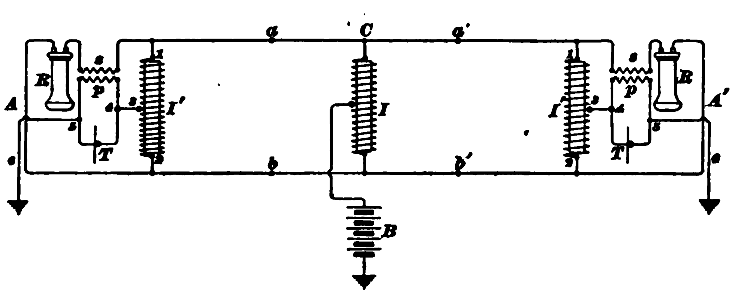


FIG. 10

the line wires, and the center point of this impedance coil is connected by wire *3* to a point *4* between the primary coil p and the microphone T in the primary circuit at the station. A point *5* on the opposite side of the primary circuit is connected by a wire *6* with the ground. The secondary coil s of the induction coil and the receiver R are connected in series in the line wire in the ordinary manner.

18. Operation of Dean System.—When two subscribers' lines are connected together, as shown, current from the battery B will flow to the center of the impedance coil I bridged across the cord circuit, where it will divide, part of it passing in multiple over the line wires to the subscriber's station A, thence through the wires *1* and *2*, and the two halves of the impedance coil I' to its center point, where

the two portions of the current unite and pass by the wire *3* to the point *4* in the primary circuit. Here the current again divides, one part passing through the primary coil *p*, and the other part through the transmitter *T* to the point *5*, where it again unites and passes by wire *6* and the ground to the negative pole of the battery *B*. In an exactly similar manner, current from the battery *B* flows through the lines to station *A'* and returns by ground to the battery. In order to understand the action of this arrangement, let it be assumed that station *A* is acting as the transmitting station and *A'* as the receiving station. Under ordinary circumstances, the current from the battery divides equally through the two branches of the primary circuit at station *A*. When, however, the transmitter *T* is caused to lower its resistance, an increased current will pass through the transmitter branch, and, as a result, the current through the primary coil will be diminished. If the resistance of the transmitter is increased, the current through it will be diminished and that through the induction coil will be increased. It thus follows that changes in the resistance of the transmitter *T* will produce corresponding fluctuations in the current flowing through the primary winding *p* of the induction coil. These fluctuations will therefore act inductively on the secondary coil *s*, thus causing induced currents to flow through the circuit formed by the line wires of each of the connected subscribers, and will therefore produce the ordinary effects on the receivers at each station. While this system is undoubtedly capable of giving good results, it has been used in but few cases, owing, probably, to the greater simplicity of the Hayes and the Stone system and arrangements whereby induction coils may be used with either of the latter systems.

Several other methods for centralizing transmitter batteries have been devised, but the ones outlined have proved their adaptability to commercial service, while the others, with some exceptions, have not.

SUBSCRIBER'S CIRCUITS

19. Transmitter and Receiver in Series.—The simplest arrangement of a subscriber's instrument for use on central-energy circuits is shown in Fig. 11. When the receiver rests on the hook, the ringing current flows from one line wire through the bell, condenser, and contact *a*, to the other line wire. The bell usually has a resistance of 500 to 1,000 ohms and the condenser a capacity of ½ to 2 microfarads. An ordinary ringing current of 15 to 20 cycles per second will readily ring an ordinary polarized bell when connected in series with a condenser of suitable capacity. For good ringing, it is advisable not to use a condenser of

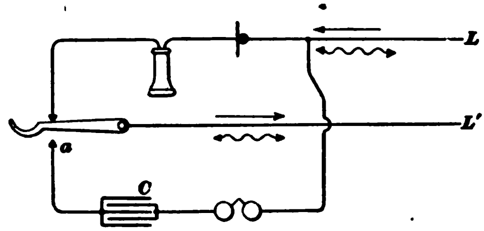


FIG. 11

less than 2 microfarads capacity with a bell wound as low as 500 ohms.

The condenser *C* may be omitted; when this is done, the bell magnets at the subscriber's station are wound to a very high resistance, in order that the current flowing through the line from the battery *B* during the time the instrument is not in use may be cut down to a minimum. As a telephone instrument is in use only a small part of the time, the continual waste of current thus produced would be a serious matter in any but a very small system, and is moreover not good for the bell winding unless it is very liberally designed, hence this arrangement is not usually advisable.

20. The bell circuit may be connected from contact *a* to the ground, instead of to line *L*, the ground then being used as a common return for all ringing currents, but is cut out when the receiver is off the hook. In either arrangement

the transmitter and receiver are connected in series across the line wires when the receiver is off the hook.

For an arrangement of this kind, the receiver should have as low a resistance as possible so as not to add to the resistance of the line, and the transmitter designed to have a high resistance, a large proportion of which is variable. 20 to 25 ohms has been found to be about the lowest resistance for an efficient receiver for such an arrangement. The one main drawback to this arrangement is that the battery current flows through the receiver. This is all right if the current passes in the direction to increase the magnetism, but the current may at some time be reversed on the line, then the receiver becomes demagnetized. Another fault is that it lacks the proper quality that many other combinations possess. However, the simple arrangement at the subscriber's station, consisting of a transmitter and receiver in series, and an 80-ohm bell between the ground and a hook-switch contact, has been used with considerable success even in large exchange systems as late as 1906, but it is now being installed only in house, hotel, and other small systems.

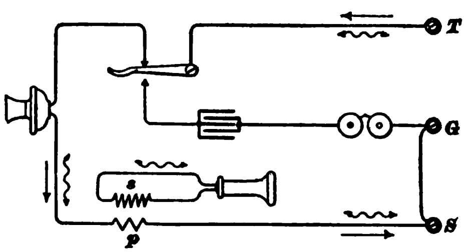


Fig. 12

21. Receiver in Closed Local Circuit.—In Fig. 12 is shown a subscriber's circuit used by several manufacturing telephone companies. The receiver is in a permanently closed local circuit containing the secondary winding *s* of an induction coil. Both battery and voice currents pass through the primary winding *p* and the transmitter, but the latter current, being fluctuating in character, induces a similar current in the secondary *s*, thereby operating the receiver. When the receiver rests on the hook, the transmitter circuit is open and the bell and a condenser are connected in series across

the signaling circuit. If a subscriber works the hook up and down to attract the attention of the operator, he receives a decided click in the ear at each make and break of the circuit, due to the current induced in the secondary by the rapid change in the strength of the current through the primary.

The binding post *T* is to be connected to the tip side of the line circuit; *S*, to the sleeve side; and for party-line service, *G*, to the ground. For a private line, binding posts *G* and *S* are connected together, as shown, and *G* is not connected to ground.

22. Impedance-Coil Circuit.—In Fig. 13 is shown a subscriber's conversation circuit in which a receiver and a condenser are connected in series and shunted by an impedance coil. The direct current from the exchange battery passes through a 25-ohm impedance coil and the transmitter, but is prevented from flowing through the receiver by the condenser, which is opaque to direct currents. The incoming voice currents, however, are prevented from flowing through the impedance coil, but find a comparatively ready path through the condenser and receiver, as indicated by the double-headed wavy arrows. This flow through the receiver is limited by a 2-microfarad condenser, which is commonly used in this circuit. Neglecting the resistance and inductance of the receiver, a ½-microfarad condenser, which is also used in this circuit, offers about four times the opposition of a 2-microfarad condenser to voice currents. The receiver and condenser constitute an almost non-inductive resistance and therefore do not distort the voice currents appreciably. The complete instrument in which this conversation circuit is used is made by the

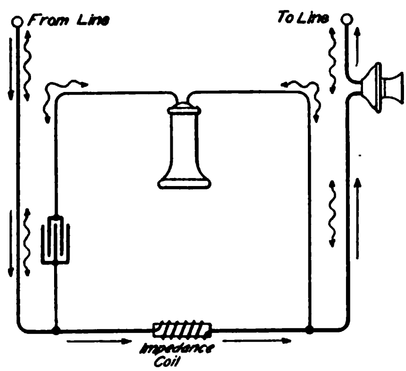


FIG. 13

Kellogg Switchboard and Supply Company, and will be further considered in connection with this Company's central-energy system.

23. Dean Central-Energy Subscriber's Circuit. The subscriber's talking circuit used in telephones made by the Dean Electric Company is shown in Fig. 14. The coils *A*, *B*, *C*, *D* are arranged in the form of a Wheatstone bridge, the usual position of the galvanometer being occupied by the receiver. *B* and *C* are non-inductively wound, while *A* and *D* are wound so as to have a high inductance. The bridge is balanced for direct currents, as indicated by the straight single-pointed arrows, by making the resistance of the four arms so that *A* is to *B* as *C* is to *D*. No direct current will then flow between the points *2* and *3*, as their potential is the same, and hence the receiver will be free from direct-current action. However, the bridge is entirely out of balance for the high-frequency voice currents which cannot penetrate the inductively wound coils *A* and *D*, and are thus forced through the receiver and non-inductive resistances *B* and *C* in the path indicated by the wavy arrows. Practically, all the voice currents flow through the receiver and there is no loss due to transformation as in instruments using induction coils.

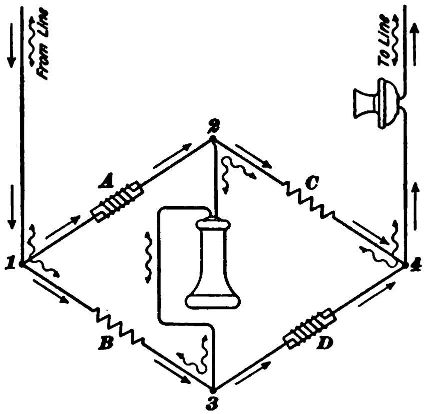


FIG. 14

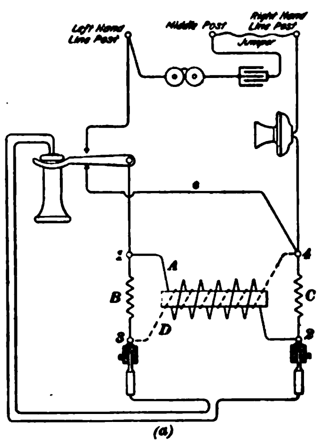
In practice, all coils of this bridge are wound on one spool and internally connected, so that, as far as external appearances or connections are concerned, it resembles an ordinary induction coil. The resistances of the four windings are approximately 20 ohms for *A* and *B*, and 30 ohms for *C* and *D*.

The total resistance of the non-inductive windings *B* and *C*, which are in series with the receiver, is therefore only 50 ohms, offering no appreciable obstacle to the voice currents. The direct current from the exchange battery passes through the two 50-ohm halves of the bridge, as indicated by the straight single-headed arrows, and thence through the transmitter. The joint resistance of these two paths is only 25 ohms, so that the transmitter obtains the full amount of current for which it is designed. Moreover, the disagreeable side tone, which is apt to interfere with good transmission, especially on long lines, and is due to excessive transmitter currents, is greatly reduced because the resistance of the two parallel paths through the bridge is low enough to shunt more or less of the variable transmitter current around the receiver.

If an operator sends a ringing current over the line while a subscriber is listening, a very disagreeable sound will be produced in most central-energy telephones, due to the relatively low frequency of the ringing current, which enables more or less of it to easily pass through the receiver. With the Dean circuit, however, it is said to be possible to connect a 100-volt ringing current directly to terminals *1* and *4* without producing a disagreeable noise in the receiver when it is held tightly to the ear. Another advantage claimed for this circuit is the reduction of the severe click caused by the ordinary manipulation of some makes of switchboard circuits.

24. The method of wiring a complete wall instrument, using the Dean circuit, is shown in Fig. 15 (*a*). The non-inductive resistances *B*, *C* are wound on the same core with the inductance coils, although not so shown in this figure. The coil has only four terminals, to two of which, *2*, *3*, the receiver cords are directly connected, thus saving any intermediate wiring. When the hook is down, the coil and receiver are shunted by the wire *e*, thus preventing any damage from lightning discharges or high-tension currents, which are liable to jump the gap between the springs of a

hook switch, thus entering and damaging the coil and receiver. The condenser and bell usually escape damage.



The Dean central-energy desk set is wired as shown in Fig. 15 (*b*), while Fig. 15 (*c*) shows a simplified diagram of the same circuit. Only one contact is controlled by the hook switch. When the receiver is lifted off the hook, the spring *e* moves to the left and closes the talking circuit. The contact is located in the base of the stand, where it, the other connections, and the impedance coil can be readily inspected. The desk cord between the stand and the desk-set

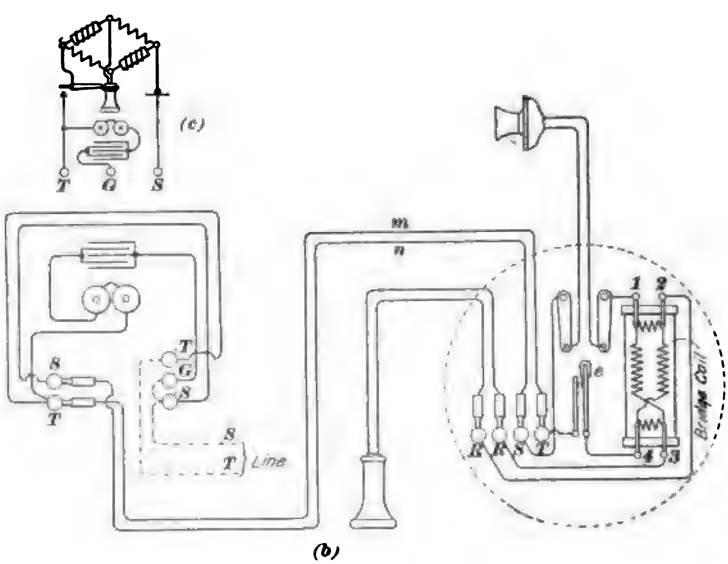


FIG. 15

box, which contains the bell and condenser, has only two conductors *m*, *n*. The desk stand can be used separately as

an extension telephone and the desk-set box separately as an extension bell.

25. The arrangement of the apparatus in the subscriber's instrument that is followed by all the Bell Companies will be shown in connection with their complete central-energy system. It should be understood that almost any subscriber's central-energy instrument may be used with almost any central-energy switchboard system, provided that the resistances in circuit when the receiver is off the hook are of proper value to operate the line-signal devices with the number of storage cells used in the exchange for that purpose. However, each manufacturing company usually designs its telephone instrument to work properly with its own switchboard system, and hence a complete system with all parts designed to work together is usually more satisfactory than any other arrangement. For instance, a transmitter that gives satisfaction on a 24-volt system might not prove satisfactory on a 40-volt system, and vice versa.

EXCHANGE CIRCUITS

26. Automatic Signaling.—One of the great advantages of common-battery systems is their adaptability to automatic signaling from the subscriber to the central office. The arrangement is such that no separate action on the part of the subscriber is necessary in order to transmit a signal to the central office, this result being accomplished by the mere removal of his receiver from its hook.

COMPLETE SYSTEM FOR SMALL EXCHANGE

27. Arrangement of Circuits.—In Fig. 16 is shown the circuits of a common-battery system for exchanges of moderate size, embracing a feature not heretofore considered. This feature consists in the use of supervisory signals in the cord circuit, by the operation of which the operator is at all times made aware of the condition of any

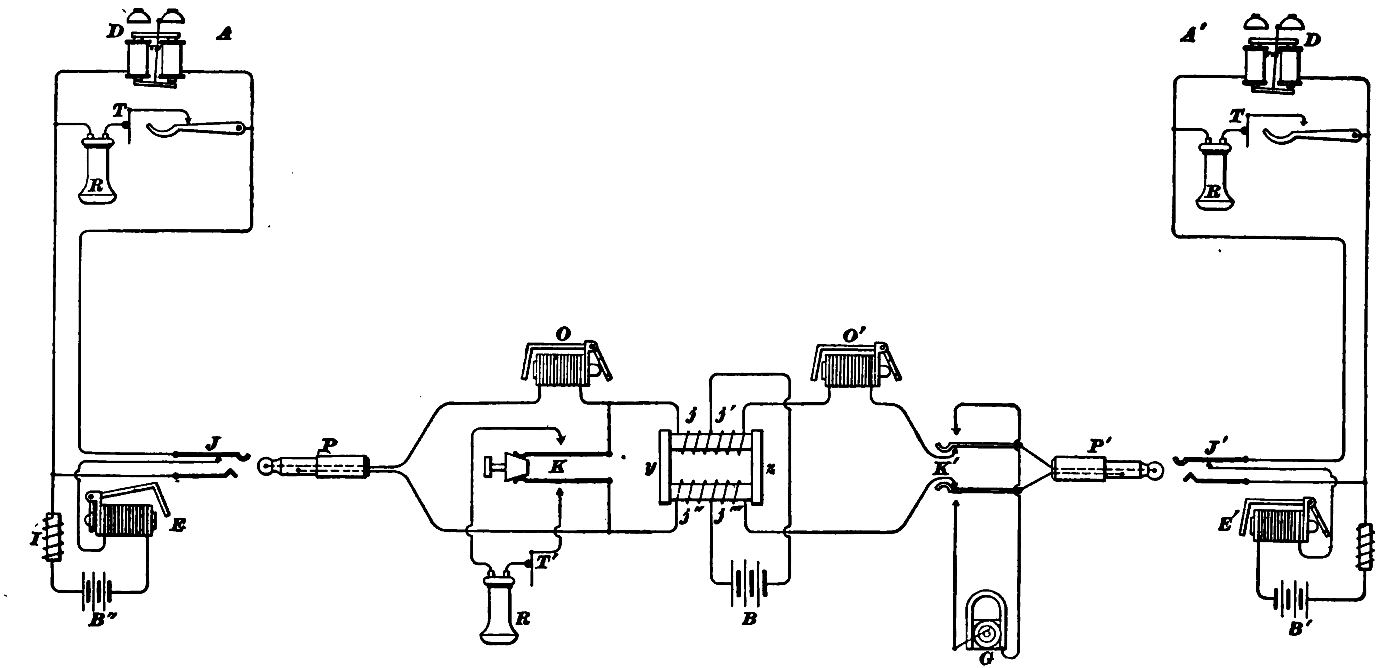


Fig. 16

two lines connected together for conversation. An electromagnetic signal E is used in the line circuit and is so arranged that the target is lifted and thus displays the line number when the magnet coil is traversed by a current, the target automatically dropping into its normal position when the current ceases. The cord circuit is arranged according to the Hayes system for supplying current to the subscribers' transmitters, the coils j, j' being wound on one iron core, and j'', j''' on the other, the magnetic circuit of the cores being completed through the two iron yoke pieces y, z. This makes the impedance to alternating currents much higher than it would be if the iron circuit were not completely closed, as would be the case were the connecting yokes y, z omitted. The terminals of the coils j, j' are connected together and to the negative pole of the battery B; the remaining terminals are connected with the tip strands of the cord circuit. In a similar manner, the coils j'', j''' are connected together and to the positive pole of the battery B, while the remaining terminals are connected with the sleeve strands of the cord circuit. Where both metallic and grounded, or common-return, systems are used in the same exchange, a repeating coil, wound as shown in Fig. 9, would be substituted for the one shown in this figure.

Connected in the tip strand of each cord are the electromagnetic signals O, O', adapted to be operated by the passage through the subscribers' talking circuits of the current from battery B. By a key K, the operator's circuit, including the transmitter T' and the receiver R, may be bridged across the circuit; and by a similar key K', the generator G may be connected with the calling plug P'.

28. Operation.—To understand the operation of the signals, assume that subscriber A desires a connection with subscriber A'. On removing his receiver from its hook, the signal E is automatically displayed by the passage of the current from battery B'' through the circuit. The operator answers with the plug P, thus opening the circuit through the signal E, which is restored by gravity. Current

from the battery B now flows through the line and cord circuit, thus causing the magnet of signal O to raise its target. Having ascertained the subscriber desired, the operator inserts plug P' into the jack of the line leading to subscriber A', and operates the ringing key K'. The insertion of the plug P' will not cause the signal O' to operate because of the high resistance (5,000 ohms) of the bell D at that station. As soon, however, as the subscriber A' takes down his receiver, a low-resistance path will be formed between the two sides of the line circuit, through the receiver and transmitter, thus allowing a comparatively large current to flow from the battery B, which will cause the target of signal O' to rise. This will inform the operator that subscriber A' has responded. If the signal O' is not raised, she will know that the subscriber has not responded and will ring him up again.

29. Supervisory Signals.—The two subscribers converse as described in connection with Fig. 6, the coils j, j'' acting as primaries and j', j''' as secondaries when subscriber A is talking. When subscriber A' is talking, the functions of the coils are reversed. Both supervisory signals O, O' remain up as long as the subscribers remain in conversation. When, however, either hangs up his receiver, the low-resistance path through his transmitter and receiver will be broken and replaced by one of high resistance through his bell, and the corresponding signal O or O' will fall, owing to the reduction in current through it. When both signals are down the operator knows that the conversation is finished. If only one falls, the other remaining up, the operator concludes that one of the subscribers desires another connection, and inquires of him what it is. A rather high non-inductive resistance or a condenser connected in parallel with each supervisory signal O, O' would improve the talking qualities of the circuit. Although three batteries are shown for the sake of clearness, only one battery would be used for all circuits.

The signals O, O' are often replaced by lamp signals, which, however, are not included directly in the cord circuit, but in

separate circuits controlled by relays placed directly in the cord circuit, in positions corresponding to the magnets of signals O, O'.

30. The Lamp Signal.—Hand in hand with automatic signaling and central-energy systems came the adoption of the incandescent lamp for signaling purposes in telephone exchanges, the lamp presenting many advantages over the electromagnetic signals so far considered. The line signals E, E', Fig. 16, may be replaced by lamp signals, but this is not satisfactory, because a short circuit on the line or a cross between opposite sides of two different line circuits will usually burn out and thus destroy the lamp and leave the subscriber with no means of calling up the exchange. Moreover, the illumination of the lamp will depend too much on the resistance of the line, which is subject to considerable variation. The resistance of the various line circuits may be practically equalized by giving the impedance coils I the proper resistance; but this does not overcome the difficulty due to the changes in the resistance of the line from short circuits or other causes. In exchanges using almost entirely cable distributing systems, this arrangement might prove satisfactory, as there the danger of line disturbances is rendered very small. However, this arrangement is not now used even in such cases.

BELL LINE AND SUBSCRIBER'S CIRCUIT

31. Lamps Controlled by Relays.—A better arrangement of the line signal is to include a relay directly in the circuit of the line wire, which relay will be operated by the change in current brought about by the change in resistance at the subscriber's station when the subscriber removes his telephone from the hook. In the local circuit of this relay is included the lamp signal and a battery, so that the current through the lamp will always be practically constant.

This feature is well shown in Fig. 17, which represents one complete subscriber's telephone and line circuit used by the Bell Companies in their large central-energy multiple

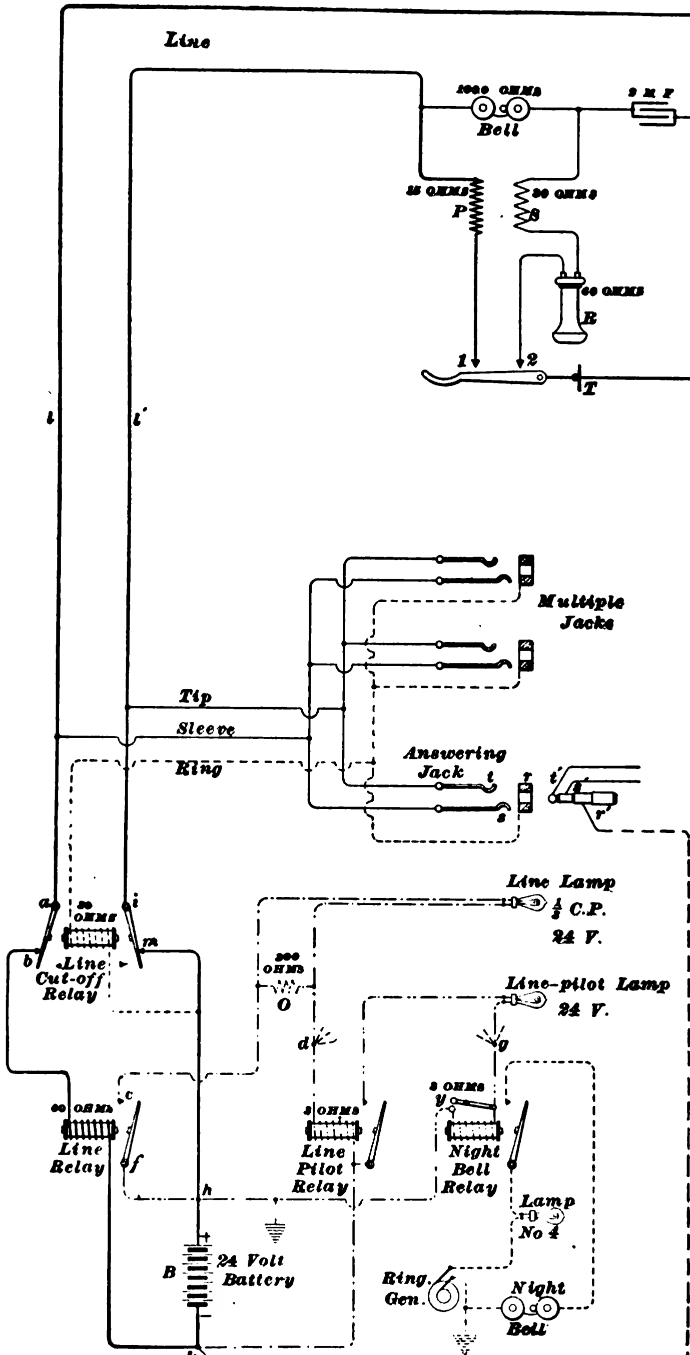

Line
1000 OHMS
Bell
2 M F
15 OHMS
P
20 OHMS
S
60 OHMS
R
1
2
T
l
l'
Multiple
Jacks
Tip
Sleeve
Ring
Answering
Jack
t
r
s
t'
s'
r'
Line Lamp
½ C.P.
24 V.
a
b
i
m
20
OHMS
Line
Cut-off
Relay
300
OHMS
O
Line-pilot Lamp
24 V.
d
g
60 OHMS
c
Line
Relay
f
h
2 OHMS
Line
Pilot
Relay
2 OHMS
y
Night
Bell
Relay
Lamp
No 4
B
24 Volt
Battery
Ring.
Gen.
Night
Bell
k

FIG. 17

switchboards. Only two multiple jacks are shown, but there are as many multiple jacks as there are sections on the switchboard. Many of the relays in this, as well as in other systems, are enclosed in brass or iron shells to protect the coils and contacts from dust and to reduce the inductive influence of one coil on others near it.

32. Normally, the subscriber's receiver *R* rests on the hook switch, and the contacts *1* and *2* are open. Hence, the condenser and bell, which are in series, normally form the only circuit between the two line wires *l*, *l'*. On account of the condenser, no battery current can normally flow through any part of the subscriber's instrument. At the frequency of the alternating current (about 15 to 20 periods per second) used for ringing the subscribers' bells, the impedance of the 1,000-ohm bell is not too great and the capacity of the condenser (2 microfarads) is large enough to allow sufficient ringing current to pass through them to properly ring the bell. Normally, the 24-volt storage battery at the central office is connected through a so-called *line relay* and the contact points *b*, *m* of the so-called *line cut-off relay*, or simply the *cut-off relay*, to the two line wires.

When the subscriber removes the receiver *R* from the hook, the transmitter *T* and primary winding *P* form a circuit of sufficiently low resistance to allow enough battery current to flow through *B*–*h*–*m*–*i*–*l'*–*P*–*1*–*T*–*l*–*a*–*b*–line relay to cause the line relay to attract its armature and close contact *c*. This allows current to flow through *B*–*h*–*f*–*c*–line lamp and resistance coil *O* (which are in parallel)–*d*–line-pilot relay–*k*. This causes the 24-volt line lamp of about ½ candlepower to light, thereby notifying the operator that her attention is desired on that line.

33. *O* is a non-inductive resistance sufficiently high not to prevent the lighting of the line lamp, but, if the line lamp should be burnt out it will still allow enough current to pass through to operate the line-pilot relay, and therefore the line-pilot lamp will light. About 1905, the Bell Companies began to remove the resistance coils *O* from

many of their large exchanges, the reason given being that the coils were unnecessary.

There is one line relay and line lamp for each line circuit, but only one line-pilot relay and one line-pilot lamp for each operator's position. That is, all the circuits at one operator's position that pass through the line lamps are collected together at some point *d* and pass as one circuit through the line-pilot relay. The line-pilot lamp is usually placed in some convenient position on the face of the board, where it can be readily seen by the supervising operator. The pilot lamps are sometimes larger and of higher candlepower than the line lamps.

Every time a line lamp becomes lighted, the line-pilot relay closes and causes the line-pilot lamp to light. This enables a supervising operator to observe whether an operator answers all calls promptly, because the line-pilot lamp goes out if a call is answered before another is received. If a line-pilot lamp remains continuously lighted an unusual length of time, the supervising operator investigates the cause. If it is due to the operator having received temporarily more calls than she can promptly answer, the supervising operator assists her; if it is due to a burned-out line lamp, she has the faulty lamp located, the call answered, and the lamp replaced by a good one.

34. Night-Bell Circuit.—As all the return conductors from all the line lamps located at one operator's position were collected together at *d* and returned as one conductor through a line-pilot relay to the battery, so all the return conductors from all the line-pilot lamps on the whole switchboard are connected together at *g* and return as one common conductor through one night-bell relay to the battery. During the day and other busy times, the night-bell switch *y* is closed, thereby short-circuiting the night-bell relay, which prevents the operation of the latter relay. During the night, or other times when but few calls are coming in, and one, or at least only a few, operators can easily attend to the entire switchboard, the switch *y* is left

open. Then the night-bell relay will attract its armature and close the circuit containing the 1,000-ohm night bell, the ringing generator, and the No. *4* lamp every time any line relay in the whole exchange closes. The No. *4* lamp is used as a resistance to reduce the strength of the current and to prevent damage to the generator should a short circuit occur. The ringing of the night bell attracts the attention of the night operator, who hunts up the operator's position where the line-pilot lamp is lighted and there finds the lighted line lamp of the calling subscriber. A night-bell circuit arranged in exactly this manner would only be used in exchanges large enough to warrant the running of a power generator or pole changer all night.

35. If a line lamp lights, the operator inserts an answering plug in the corresponding answering jack, the tip and sleeve contacts t', s' make contact, respectively, with the tip and sleeve springs t, s of the answering jack, thus connecting the cord circuit with the line in the ordinary manner. A third contact r' on the plug makes connection with the ring r of the jack, thus completing a circuit from the battery B through h–line cut-off relay–r–r'–to B. This energizes the line cut-off relay, causing it to attract its armature, thus breaking the circuit at points b, m and cutting off the line beyond the spring jack. The breaking of the circuit at points b, m also opens the circuit of battery B through the line relay, which releases its armature and opens the circuit containing the battery B, the line lamp, and the line-pilot relay, which, in turn, releases its armature and opens the line-pilot lamp circuit. Hence, both the line and line-pilot lamps are extinguished. A full explanation of the operation of the cord and subscriber's instrument will be given in connection with the Bell central-energy system.

36. As the line signals in central-energy systems are usually lamps controlled by relays associated with the line circuit, so the supervisory signals are also usually lamps controlled by relays associated with the cord circuit. For instance, in Fig. 16 the supervisory signals O, O' may be

replaced by relays that control lamps placed in separate local circuits. The circuits of supervisory relays and lamps will be considered in connection with the various central-energy systems.

The lamps used as signals are usually covered with glass caps, called *opals*, of different colors so as to be easily distinguished. Thus, the opals for the line lamps may be white, for the supervisory lamps red, and for the line-pilot lamps blue.

37. Ground on Central-Energy Systems.—In central-energy telephone systems, it is usually customary to ground the positive side of the common battery. One object of this ground is to render the various lines less susceptible to inductive disturbances. For example, if a line having a low insulation or a ground at some point should happen to be connected to another poorly insulated line, the first line may become noisy and render the other line noisy also, because the disturbing currents entering the first line can only find a path to ground through the low insulation of the second line. If, on the other hand, a centrally located battery is grounded, the disturbing currents coming in from either line can pass to earth through the ground at the central battery and leave the other line affected but little if at all.

The positive terminal of the battery is grounded because it is considered that a ground at this point will cause less difficulty from **electrolysis**, that is, from the eating away of the conductors and lead sheaths. This is due to the fact that the leakage currents, whose direction is from the ground into the wires or lead sheaths of the cables, are distributed over so large a territory that they are not of sufficient intensity at any one point to produce much, if any, electrolytic action, except perhaps at the central-battery ground, where all the leakage currents reunite. This central-office ground can be so well made that no difficulty will occur at that point, and if it does the trouble can be easily remedied. Injury from electrolysis only occurs where a current passes from a wire or lead cable into the ground, and as the leakage

currents flow in the opposite direction when the positive terminal of the battery is grounded, that is, from the ground into the wires and cables, little or no electrolysis will result.

One side of the ringing circuit is usually grounded, because in most telephone exchanges selective ringing on party lines is obtained by using one line and the ground as a ringing circuit, both wires being used while talking. As this custom is so prevalent, the ringing generators are usually grounded. Where the ground is not used as one path for the ringing current, however, it is not necessary to ground the ringing generator.

38. Current Required.—In central-energy systems, the current should be sufficient for transmitters on the longest lines, but at the same time not enough to injure the transmitter on the shortest line. It is good practice to provide for the long lines and let the short ones take care of themselves. The transmitter should be designed to stand the current.

The voltage of the battery should be great enough to operate all signals over the longest lines, but the signals should be quite sensitive, so that an excessive voltage will not be necessary. A very high voltage is very apt to injure the transmitters, causing them to sizzle and fry; besides, it is only an additional expense and not usually necessary in a well-designed system, unless the lines are unusually long.

In a 24-volt system, subscribers' transmitters usually require from .05 to .1 ampere; operators' transmitters about .12 ampere; line, supervisory, and pilot lamps about .06 ampere; cut-off relays about .05 ampere; and subscribers' bells about .2 ampere at 80 volts. These values will vary considerably, depending on the voltage of the battery, the arrangement of the circuits, and the resistances of relays, coils, etc.

KIND OF SWITCHBOARD TO USE

39. Although magneto-call multiple switchboards have been extensively used and are still in use, they are being rapidly crowded out by central-energy multiple systems,

because the latter are more economical to operate and give much better satisfaction to both subscribers and owners of telephone systems, although the magneto-call switchboard may be somewhat cheaper to install. The simplicity of operation and construction and the low first cost of the subscribers' telephone instruments is a very advantageous feature of central-energy systems and more than equalizes the more expensive and complicated switchboard circuits required. The older type of magneto-call switchboards are also inferior to common-battery signal systems having local transmitter batteries, in economy and rapidity of operation.

40. For small- and medium-sized exchanges, several companies now make so-called lamp-signal magneto-switchboards having one line and two supervisory lamps, which operate in the same manner as on complete central-energy systems. By means of a new lamp-signal magneto-switchboard, which can later be readily rewired without discarding the switchboard apparatus for a complete central-energy system, the magneto-telephones may be retained without rewiring or change, and the method of operation brought up to the standard of central-energy systems, except that the subscriber must use his hand generator to call up the exchange and to ring off. Such a system may be obtained by the use of electrically locking line relays that control a local circuit containing the line lamp and a battery. In the middle of the sleeve and tip conductors of each cord circuit, there may be a condenser; while a high-wound iron-clad relay that controls a supervisory lamp circuit is bridged across the answering and another across the calling end of each cord circuit. The electrically locking line relay is disconnected from the line and its electrically locking circuit automatically opened by the insertion of a plug in the line jack. Instead of such relays, target signals may be used, thus avoiding the use of lamps.

41. While central-energy systems are rapidly displacing magneto-exchanges even for small installations, nevertheless some consider a centralized calling system with local

transmitter batteries more successful from the standpoint of speech transmission and economy of operation. Of the multitude of common-battery systems on the market, it cannot be truthfully claimed for one of them that its talking qualities are any better if as good as that obtained from a local-battery system with primary batteries in good condition, especially for long-distance work. Nevertheless, the transmission is more constant on central-energy systems and never reaches the low efficiency obtained on local-battery systems when the local primary batteries are defective, run down, or exhausted.

42. Experience seems to show that the complete central-energy system is more efficient, more adaptable to various kinds of service and requirements, more rapid and economical to maintain for exchanges exceeding about 1,200 lines than any other system. The Bell Company is apparently advocating the use of central-energy systems, not necessarily its most complete system, for all new exchanges of 1,000 subscribers and over.

Up to about 300 lines, the simple magneto-switchboard is probably most economical; and for exchanges that expect to reach about 1,000 lines a centralized calling system with local transmitter batteries is most economical. On many centralized calling systems, self-restoring targets have been used; but targets are not now considered as good as lamps on account of the extra space required by the targets, the fact that their use introduces moving parts into the switchboard face where they are difficult to get at when operating, and the difference in cost between lamp-signal and target boards is less than formerly. All large manufacturers and telephone engineers now advocate lamp signals and complete central-energy systems for smaller exchanges than formerly; probably because of the better and cheaper central-energy apparatus now obtainable.

On central-energy systems having relays or impedance coils permanently bridged across the line circuit, the ringing of subscriber's bells is usually rather poor and the relays are apt to chatter while ringing.

CENTRAL-ENERGY SYSTEMS

CENTRAL-ENERGY SWITCHBOARD CIRCUITS

INTRODUCTION

1. At the present time, there is a demand for three types of central-energy multiple switchboard systems—a *full two-wire system*, a *full three-wire system*, and a combination of the two, or a system using *three-wire line and two-wire cord circuits*. Considering each type as equally well developed, the three-wire system has the greatest flexibility in operation, the combined system comes next in order, and the full two-wire system last.

The full **three-wire system** is the most flexible as the third strand is usually connected in a local circuit so as to insure the office signaling conditions, thereby leaving the talking circuit entirely free from any complications. This gives the best possible conditions for long-distance service as both sides of the lines are free from apparatus and shunt connections; also, special coin-controlled mechanisms at the subscribers' stations, measured-service devices, etc. can be satisfactorily operated. Also, since both sides of the line are entirely clear, the wire chief can test directly from the multiple jacks without taking into consideration any special conditions that are inherent in the two-wire circuits.

2. A combined **three-wire line and two-wire cord circuit** gives practically all the flexibility of the full three-wire system with the advantage of two conductor cords and

plugs with their corresponding smaller maintenance expense. With this system, the trunks and test cords can be of the three-strand variety, thereby giving the system the principal advantage of the full three-wire system—a calling metallic line circuit for long-distance and test purposes.

3. As the straight **two-wire system** eliminates one of the conductors from each line circuit in the office cables and in some cases one contact from the jack, it offers a considerable saving in the first cost, when figured in dollars and cents. This is a slight advantage, however, as when once installed the actual maintenance of both the two-wire and the three-wire line circuits are practically the same, the quality of equipment being considered as equal. This is due to the fact that the actual wear of properly designed jacks employing two or three contacts is the same as far as the operation is affected. The cables in both cases, having no mechanical work to perform, can be considered as having the same maintenance cost.

A two-wire line circuit has another advantage in that the weight per line in the multiple cable is practically two-thirds of that of the system using the three-wire line circuit. However, the question of weight has been overcome by properly designing the metal framework of the switchboard sections and providing ready means for removing the jacks for inspection and repairs.

A full two-wire system is greatly limited in its usefulness, as the presence of the cut-off relay when legged from one side of the talking circuit to ground greatly reduces the flexibility that is required in modern telephone practice. The two-wire system does not so readily allow the use of meters and party-line systems that require the flow of ringing current over either line wire. However, the Dean or Kellogg harmonic four-party system may be used. In fact, engineers of large independent telephone operating companies are now specifying multiple-switchboard systems with three-wire line circuits to be used in combination with either two-wire or three-wire cord circuits.

COMPARISON OF CENTRAL-ENERGY SYSTEMS

4. Satisfactory operation and a good talking circuit should be the first consideration in any common-battery system. Then the more simple the apparatus, the less will be the trouble and expense for repairs, assuming the apparatus of the various systems to be equally well made and reliable. Furthermore, the less the first cost, the less will be the capital required and the interest on the equipment that must come out of the earnings of the company each year. Another point that enters into the economical operation of a central-energy system, and which becomes more important as the number of subscribers increase, is the amount of energy required in a line and cord circuit. Other things being equal, it is desirable to have as small a consumption of energy as possible. Since different voltages are used, it is somewhat difficult to make a comparison of the various systems in this respect. Where it is desirable to estimate the total energy required, it may be done by calculating the current required in each line and cord circuit and multiplying the total current by the electromotive force of the common battery, thus obtaining the total number of watts consumed in one circuit while in use. If all the current that operates the various relays also passes through the subscriber circuit to supply the transmitter, the current is used to good advantage and none is wasted.

STROMBERG-CARLSON CENTRAL-ENERGY SYSTEMS

TWO-WIRE CIRCUIT

5. Fig. 1 shows the connections of a two-wire line and cord, central-energy, multiple switchboard said to have been installed in at least one and probably in a number of large exchanges since 1901 by the Stromberg-Carlson Telephone Manufacturing Company. The resistances of the various

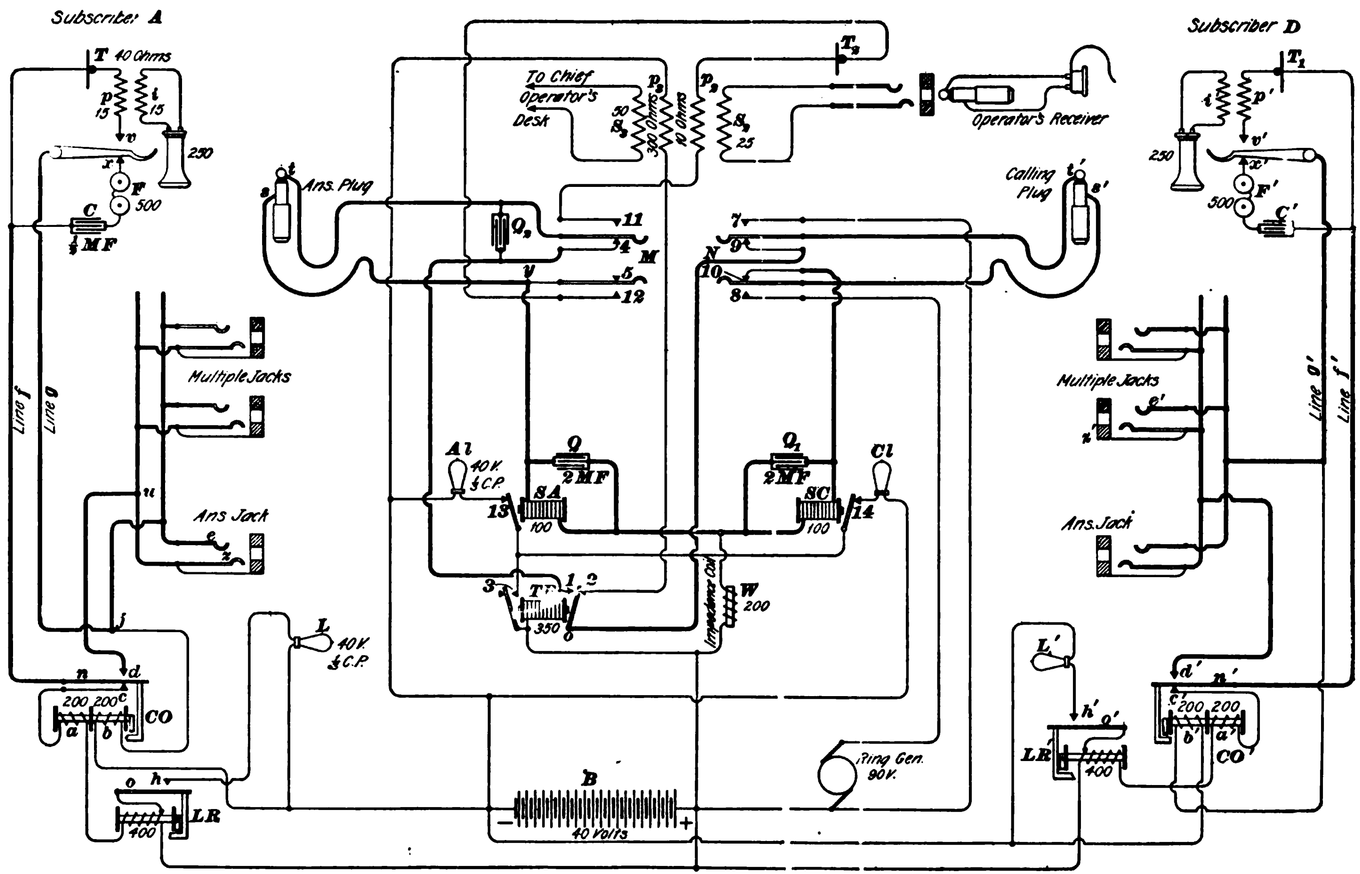

Subscriber A
Subscriber D
T 40 Ohms
Line f
Line g
Line g'
Line f'
Multiple Jacks
Ans. Jack
Ans. Plug
Calling Plug
To Chief Operator's Desk
Operator's Receiver
300 Ohms
10 Ohms
Impedance Coil
Ring Gen. 90V.
40 Volts
40V. ½C.P.

FIG. 1

coils, capacities of condensers, candlepower of lamps, voltage, etc. are given, as far as practical, on the diagram; all relays and switches are shown in their normal positions. A differentially wound cut-off relay *C O* is associated with each line circuit. The oppositely wound coils of this relay, when both are connected in series with the battery, serve to exert a neutralizing effect on each other, so that the spring *n*, which rests normally against the contact stop *c*, will not be moved. This condition exists when there is no plug in any jack of the line with which this cut-off relay is associated.

In the subscriber's telephone, the primary winding *p* and transmitter *T* are connected in series and to the line wire *f*. When the 250-ohm receiver rests on the hook, the circuit is open at contact *v*, but the 500-ohm bell *F* and ½-microfarad condenser *C* are connected in series from line *f* through contact *x* to line *g*. Since the condenser will allow no battery current to flow through it, the line is open as far as the battery current is concerned, but an alternating current can readily pass through it and ring the bell. The multiple jacks are placed on ½-inch centers.

When the line and cut-off relays operate, their armatures are lifted, thus raising the springs *o*, *n*. The actual construction of relays will be shown in another Section along with other switchboard apparatus.

6. Operation.—When subscriber *A* removes his receiver from the hook, the bell and condenser are disconnected from the line circuit and the transmitter *T*, having a resistance of about 40 ohms, and the primary winding *p* of the induction coil, having a resistance of about 15 ohms, are connected in series across the two line wires, thereby allowing sufficient current to flow from the positive terminal of the common battery *B*, through the winding of the line relay *L R*–coil *a*–contact *c*–spring *n*–line *f*–subscriber's transmitter *T*–primary coil *p*–contact *v*–line *g*–coil *b*, to operate the line relay *L R*, which has a comparatively high resistance, 400 ohms, and therefore requires but little current. The contact *h* being closed by the operation of the line relay, the line lamp *L* is

lighted. The same current flows through both coils *a* and *b*, but it circulates around the iron core in opposite directions, and hence, the cut-off relay *C O* is not now affected.

When the line lamp lights, the operator inserts the answering plug in the answering jack. Current then flows from $+B$ through the so-called tip relay *T R*–contact *4*–tip *t* of the answering plug–spring *e* of the answering jack to point *j*; current also flows from $+B$ through the line relay *L R*–coil *a* –contact *c*–lever *n*–line *f*–subscriber's transmitter and primary coil and line *g* to the same point *j*. The two currents here unite and flow through coil *b* to $-B$. Although the current in coils *a* and *b* flows around the core in opposite directions, the current in coil *b* is sufficiently greater than that in *a* to energize the cut-off relay, thus opening *c* and closing *d*, and thereby transferring line *f* from coil *a* to the sleeve springs of all jacks associated with that line and through the supervisory relay *S A* on the answering side of the cord circuit and the impedance coil *W* to $+B$. Consequently, this supervisory relay and the impedance coil replace the coil *a* and line relay *L R*, and the cut-off relay *C O* continues to be held in a closed position. Current being cut off, by the opening of the circuit at *c*, from the line relay *L R*, the circuit containing the line lamp *L* is opened at *h* and hence the line lamp goes out. Since current flows through the supervisory relay *S A*, the circuit containing the supervisory lamp *A l* is open at *13* and the lamp does not light.

7. The operator then closes the listening key *M*, thereby opening at contact *4* the circuit through the tip relay *T R* and closing at *11*, *12* a circuit through the operator's transmitter T_1 and the winding p_1 of her induction coil. The present condition of the circuit is shown in Fig. 2, all unnecessary connections being omitted, but the same letters are used as in the previous figure, so that the circuits that will be mentioned in this connection may be readily traced in either figure. Current now flows from $+B$ through the impedance coil *W* and supervisory relay *S A* to the point *y*, where it divides, part flowing through the sleeve *s*–spring *z*

–contact *d*–spring *n*–line *f*–subscriber's instrument and line *g* to point *j*; the other part of the current flows from *y* through contact *12*–transmitter T_2–primary winding p_2 of the operator's induction coil–contact *11*–tip *t*–spring *e* to point *j*; here the two currents unite and flow through one coil *b* of the cutt-off relay, which is not shown in Fig. 2, to the battery *B*. Thus, current is supplied from the common battery to the operator's and subscriber's circuits in parallel, and hence, the operator and subscriber *A* can converse with each other.

Thus there is an inductive resistance of 200 + 200 + 100 = 500 ohms in series with both the subscriber's and operator's talking circuits, which are now in parallel; however,

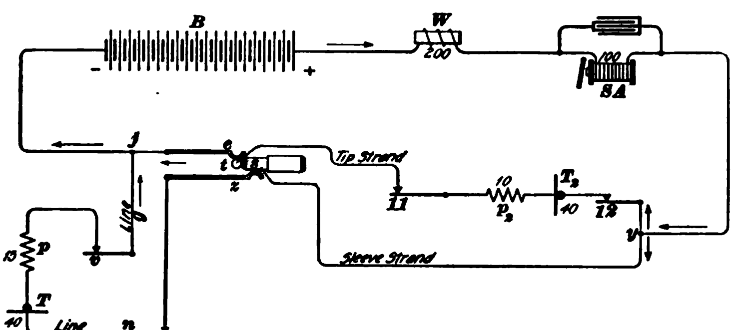


FIG. 2

the 100 ohms is shunted by the condenser so that it offers little impedance to fluctuating currents. A change in resistance of either microphone transmitter readily produces a variable current in the other circuit because the inductive resistances tend to exclude such fluctuations from the circuit containing them, and, consequently, a greater variable current in one of the parallel circuits is obtained by diminishing the current in the other parallel circuit. The necessary fluctuations in the two talking circuits are thereby readily secured.

8. Busy Test.—The operator having learned what subscriber is wanted, proceeds to make the busy test by touching the tip *t'*, Fig. 1, of the calling plug to the sleeve contact

of some jack associated with the line desired. The line will test clear until some operator inserts a plug into a jack of that line at any section of the switchboard, because the sleeve contacts of all jacks in any one line circuit are dead, that is, on open circuit, as long as contact d' is open. Thus a line will not test busy if a receiver has been removed from its hook and before some operator inserts a plug into the answering jack. However, this is usually a very short time indeed and this condition is common to many exchange systems.

Suppose that an operator at some other section of the multiple board has inserted a plug into the jack of the line going to subscriber *D*. As in the case of the line circuit of sub-

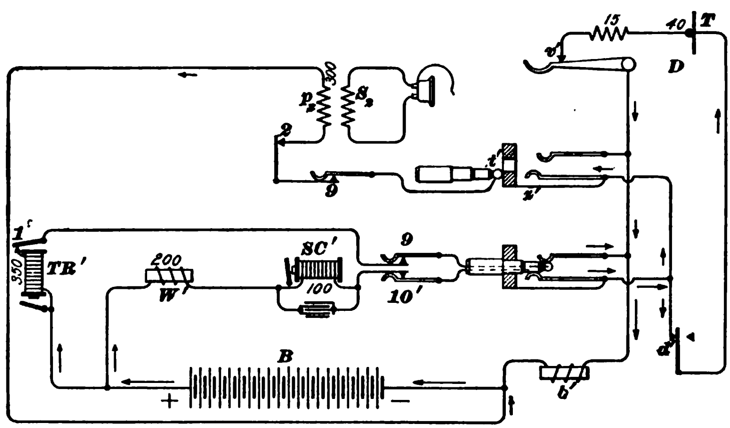


Fig. 3

scriber *A*, the line relay *L R'* and coil a' will be cut out and the sleeve side of the line will be connected through a supervisory relay and an impedance coil to the positive terminal of the battery. This circuit, containing a supervisory relay *S C'* and an impedance coil *W''*, is shown in Fig. 3. Thus the sleeves of all jacks in a busy line have a potential that will cause current to flow through the tip t' of the plug used in making the test–contact 9–contact 2–winding p_2 of the operator's induction coil to $-B$. This current flowing through p_2 induces a current in S_2 that produces the usual busy click in the operator's receiver. The various circuits

concerned while this test is being made are shown in this figure, the arrows indicating the direction and also, very roughly, the relative strengths of the currents in the various circuits when the subscriber's receiver is removed from the hook and a plug has been inserted in one jack. If the subscriber's receiver rests on the hook, contact *v'* will be open and no current will flow through the subscriber's telephone *D*; however, this will not prevent the production of a busy-test click, although it may be somewhat weaker.

9. If the line is not busy, the operator releases her listening key *M*, Fig. 1, inserts the calling plug in the jack, and closes the ringing key. The release of the listening key allows current to flow from $+B$ through the tip relay *TR*-contact *4*–tip *t*–tip spring *e*–coil *b* to $-B$, and also from $+B$ through the impedance coil *W*–supervisory relay *SA*–sleeve *s*–sleeve spring *z*–contact *d*–spring *n*–subscriber's line circuit–coil *b* to $-B$. Thus the tip relay *TR* and the supervisory relay *SA* attract their armatures and the line cut-off relay *CO* remains closed, as before. Although the circuit of the supervisory lamp *Al* is closed at *3*, it is open at *13*, and, consequently, the lamp *Al* does not light. However, the calling supervisory lamp *Cl* lights, its circuit being closed at *14* because the called subscriber's receiver is still on its hook and hence the circuit is open at *d'*, and, consequently, no current can flow through the supervisory relay *SC*. The supervisory lamp *Cl* remains lighted until the called subscriber removes the receiver from its hook, thereby allowing current to flow through the supervisory relay *SC* and the subscriber's circuit, thus opening the circuit of the supervisory lamp *Cl* at contact *14*. Moreover, the closing of the circuit at contact *1* of relay *TR* connects together the tip strands of the calling and answering plugs, thereby completing the circuit between the two subscribers' lines and also cutting out the coil p_3, which is required only for making the busy test.

When the ringing key *N* is closed, current from $+B$, Fig. 1, flows through contact *7*–tip *t'*–spring *c'*–coil *b'*, thus

holding the line cut-off relay CO' closed, since no current can flow through the coil a', because the subscriber's circuit is open at v', and, consequently, alternating current from the ringing generator can flow through contact 7–tip t'–spring e'–contact x'–bell F'–condenser C'–spring n'–contact d'–sleeve s'–contact 8 to the generator and, therefore, the called subscriber's bell is rung.

10. Having rung up subscriber D, and both listening and ringing keys being now in their normal positions, the two subscribers A and D can converse as soon as D removes

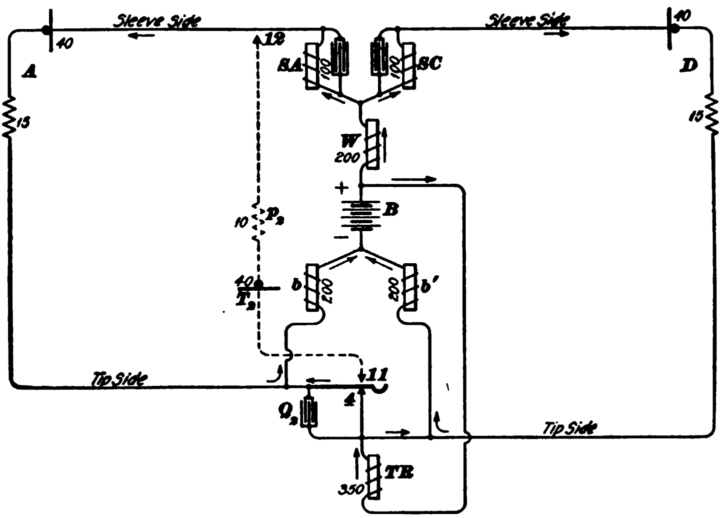


FIG. 4

his receiver from its hook. The circuits concerned during the conversation are shown in Fig. 4. It will be noticed that b, b', and W act as impedance coils about as in the Stone central-energy arrangement. Since the coils of the supervisory relays SA and SC are shunted by condensers, the voice currents readily pass through the condensers, instead of being forced through the coils, from one line to the other. There are no coils whatever in series in the other side of the line circuit. The two subscribers' circuits are in parallel as

far as battery B is concerned, and the one battery supplies both circuits with the current required for their transmitters.

The condenser Q_s enables the operator to listen in, if desirable, while the two subscribers' lines are connected together and without interfering perceptibly if they happen to be conversing. If the listening key is closed, the operator's telephone set is connected across the tip and sleeve strands of the circuit at contacts *11* and *12*, but the fluctuating currents from one subscriber's line to another are not interrupted, although the circuit has been opened at contact *4*, because they can now pass from t', Fig. 1, through the circuit, *9-o-1*-condenser Q_s to t instead of through *9-o-1-4* to t. Although the current from the battery is interrupted at contact *4*, enough current can still flow from $+B$ through TR-*1-o-9*-t'-e'-b' to $-B$, to hold the tip relay TR closed.

When the conversation is finished, the supervisory lamp $C\,l$ will light as subscriber D replaces his receiver on its hook and the supervisory lamp $A\,l$ will light as subscriber A hangs up his receiver. The operator then removes both plugs and all circuits are restored to their normal condition.

CURRENT CONSUMPTION

11. To show the method employed in computing the energy required per connection, the following calculations have been made for the central-energy multiple-switchboard system just described. The power required for ringing will not be considered, as it will be about the same for all types of switchboards. The following consumption of current supplied by the storage battery is computed on the basis that, on lamp-signal, central-energy, multiple switchboards, the average length of time for operators to answer a call is 5 seconds; that it requires 3 seconds for the operator to get the number desired, test the line desired, and insert the calling plug in the jack; that it requires 15 seconds for the called subscriber to answer, that the average length of conversation is 2 minutes, and that it requires 5 seconds for the

operator to disconnect. The detailed current consumption with a battery of 40 volts and a line resistance of 100 ohms is as follows:

12. Current Consumption Before Call is Answered. The length of time that elapses from the moment the subscriber takes down his receiver until the operator inserts her answering plug in the jack with the listening key closed will average 5 seconds. In series with the 100-ohm line circuits are the coils *a*, *b*, Fig. 1, of the cut-off relay and the winding of the line relay, giving a total resistance of $400 + 200 + 100 + 200 = 900$ ohms. The current through this circuit is $\frac{40}{900} = .044$ ampere. The current required by the line lamp is .1 ampere. The total current is $.1 + .044 = .144$ ampere and the current consumption is $.144 \times \frac{5}{60} = .012$ ampere-minute.

13. Calling Subscriber's Current Consumption. From the moment the operator answers a call until she releases her listening key, current flows, for say 3 seconds, through (see Fig. 4) *W–SA*–subscriber's line and operator's circuit in parallel–coil *b*. The operator's circuit is about 50 ohms, subscriber's circuit 100 ohms; their joint resistance is $\frac{50 \times 100}{50 + 100} = 33.3$ ohms. The total resistance is, therefore, about $200 + 100 + 33 + 200 = 533$ ohms. The current is $\frac{40}{533} = .075$ ampere. Ampere-minute consumption is $.075 \times \frac{3}{60} = .00375$, or, say, .0038 ampere-minute.

14. Called Subscriber's Current Consumption. From the moment the operator releases her listening key and inserts the calling plug in the jack, the operator's circuit is disconnected and the relay *TR* is in parallel with *W–SA*–subscriber's circuit, giving a joint resistance of $\frac{350 \times (200 + 100 + 100)}{350 + 200 + 100 + 100} = 186$ ohms. The current through this resistance returns through *b* and *b'*, which are in parallel; their joint resistance, being one-half of 200, is 100 ohms. Hence, the total resistance is 286 ohms. The current is $\frac{40}{286} = .14$ ampere, giving $.14 \times \frac{15}{60} = .035$ ampere-minute.

Current also flows through the calling supervisory lamp Cl for 15 seconds. The current through this lamp is .1 ampere, giving $.1 \times \frac{15}{60} = .025$ ampere-minute. Total consumption for the 15 seconds is $.035 + .025 = .06$ ampere-minute.

15. Current Consumption During Conversation.
Length of conversation is 2 minutes. In each subscriber's circuit is one supervisory relay (see Fig. 4), giving each line a resistance of 200 ohms. These two circuits are in parallel; their joint resistance is 100 ohms. This resistance is in series with W, giving a resistance of $200 + 100 = 300$ ohms. This resistance is in parallel with TR, giving a joint resistance of $\frac{350 \times 300}{350 + 300} = 162$ ohms. In series with this resistance are the two 200-ohm coils b, b', which are in parallel. Their joint resistance is 100 ohms. Hence, the total resistance of the circuit is $162 + 100 = 262$ ohms, the current is $\frac{40}{262} = .152$ ampere, and the total consumption is $.152 \times 2 = .304$ ampere-minute.

16. Current Consumption During Disconnection.
Length of time required to disconnect is 5 seconds. Both subscribers' line circuits are now open, hence current flows (see Fig. 4) through TR and the two coils b, b', which are in parallel. The resistance of this circuit is $\frac{350 \times 100}{350 + 100} = 78$ ohms, and the current is $\frac{40}{78} = .51$ ampere. The current in each supervisory lamp is .1 ampere, or .2 ampere in both lamps. The total current is $.51 + .2 = .71$ ampere. The current consumption is $.71 \times \frac{5}{60} = .059$ ampere-minute for disconnection.

17. Total Current Consumption.—The total ampere-minute consumption is $.012 + .0038 + .06 + .304 + .059 = .4388$ ampere-minute. This will give $\frac{.4388}{60} = .0073$ ampere-hour consumed per connection. The energy consumed per connection is $.0073 \times 40 = .292$ watt-hour. These calculations are based, according to the makers of this system, on a low line resistance; they state that the average resistance of

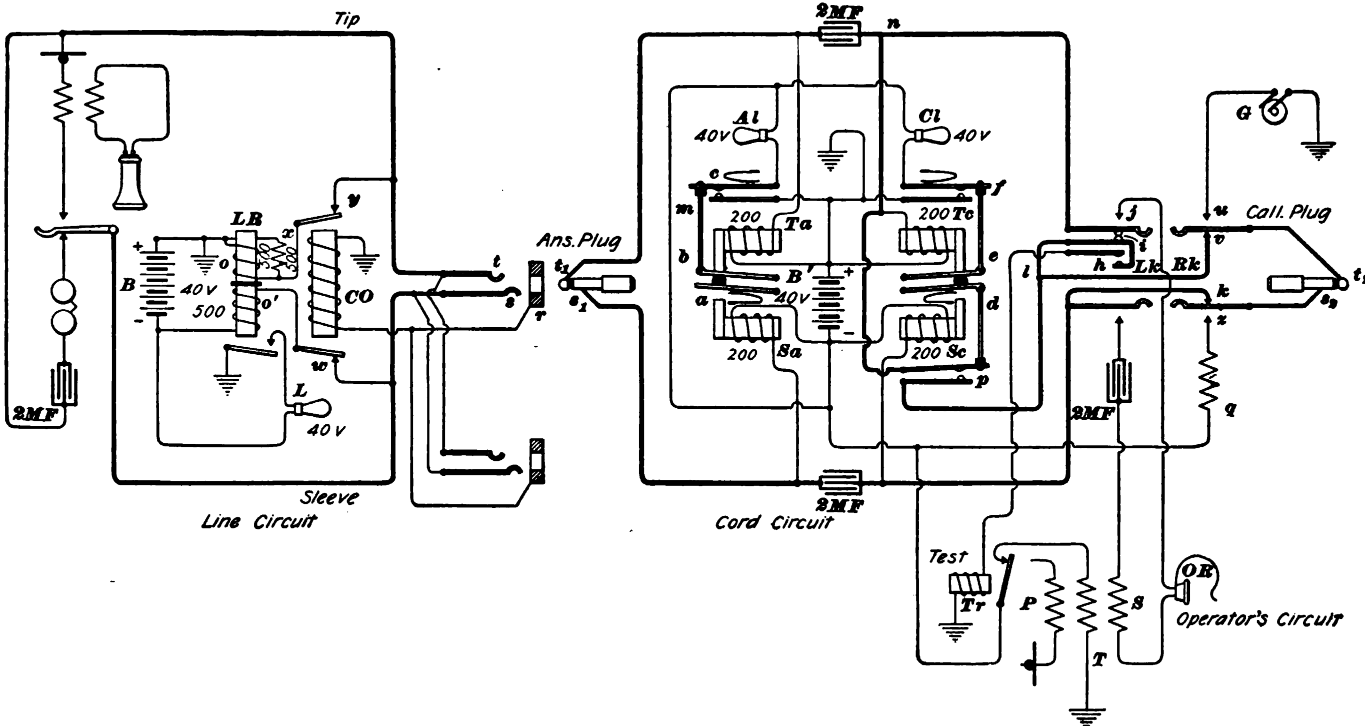

Tip
Sleeve
Line Circuit
LB
CO
B
40 v
500
L
40 v
2MF
Ans. Plug
2MF
n
Al
40 v
Cl
40 v
200
Ta
200
Tc
B'
40 v
200
Sa
200
Sc
2MF
Cord Circuit
Lk
Rk
Call. Plug
G
2MF
q
Test
Tr
P
T
S
OR
Operator's Circuit

FIG. 5

a central-energy line circuit during conversation will be approximately 300 ohms instead of 100 ohms as used in these calculations.

THREE-WIRE LINE AND TWO-WIRE CORD CIRCUIT

18. The line and cord circuits shown in Fig. 5 are the latest (1905) circuits of the Stromberg-Carlson Company, the line circuit is of the three-strand variety, while the cord circuit is two-strand. The line circuit has line and cut-off relays, the latter operated by current obtained through the sleeve of the plug. The sleeve s_1 of the answering plug connects together the ring r and the sleeve s of the jack when inserted, thus, for all intents and purposes, making the line circuit two-strand. There are, however, many advantages in using a third-strand connection to the cut-off relay, the principal one being the clear line circuit obtained for toll, trunk, or test connections, a three-strand cord being used in such cases. The two-strand cord circuit is sufficiently flexible in operation to make all local connections and on account of its decreased wearing parts is used in preference to a full three-strand cord circuit.

The 500-ohm non-inductive resistance x interposed between the tip side of line and the ground side of battery in parallel with the winding o has nothing to do with the operation of the line relay $L\,R$, and is wound on its spool for convenience only. It is said to be used so that when the cut-off relay $C\,O$ operates, due to inserting a plug in the jack, the current change in the circuit will not be of enough magnitude to give a disagreeable click in the waiting subscriber's ear. That it does this when connected as shown seems doubtful.

19. The four relays Ta, Sa, Tc, Sc in the cord circuit are mounted under one square aluminum shell or cover, the two answering, as well as the two calling, relays being mechanically interconnected. Springs have been added to indicate the direction in which the contact springs tend to move, the lower spring being the stronger of the two. Thus, for example, when current flows through the sleeve

answering relay *Sa* its armature *a* is drawn down and the armature *b* of the tip answering relay *Ta* falls with it, because the normal tendency of the armature and contact spring of the latter is downwards. The normal tendency of the armature *a* is upwards. The link *m* transmits the motion of the armature *b* to the contact spring, closing the normally open contact *c* when *b* is not attracted and when it follows *a* downwards. If current flows through the tip answering relay *Ta*, its armature *b* will be drawn up, thus opening the contact *c*. The armatures *a* and *b* are thus separated, each being drawn to its respective pole piece.

20. Operation.—When a subscriber takes down his receiver, current flows from $+B$ through *o* and *x* in parallel–*y*–subscriber's line and instrument–*w*–*o′* to $-B$, thereby operating the line relay *LR* and lighting the line lamp *L*. Inserting the answering plug in the answering jack allows current to flow through the tip answering relay *Ta*, which, therefore, holds up its armature *b* and keeps the contact *c* open. The relay *Sa* also attracts its armature, but this will not cause contact *c* to close.

Inserting the calling plug in a jack of the line desired allows current to flow through *B′*–*Sc*–sleeve strand–ring of jack and cut-off relay of line desired–ground–*B′*. Closing the ringing key not only allows ringing current to flow from *G* through *u*–t_1–subscriber's line–condenser and bell–s_1–*z*–*q*–*B′*–ground–*G*, but also through *B′*–resistance *q*–*z*–s_1–ring of jack–cut-off relay to ground. This is necessary in order that the cut-off relay may be held closed even while ringing. The flow of ringing current through the battery does not interfere with or harm the battery and it is only the internal resistance of the battery that opposes the alternating ringing current.

21. Before the desired subscriber responds, current flows only through *B′*–relay *Sc*–sleeve s_1–ring of jack–cut-off relay–ground, thus closing *p* and allowing the armature *e* to follow the armature *d* down and close contacts *f*, thereby lighting the calling supervisory lamp *Cl*. The closing of *p* has no

effect at this time. When the desired subscriber takes down the receiver, current also flows through B'–Tc–$\left\{\begin{matrix} n\text{–}i \\ p \end{matrix}\right\}$–$l$–$v$–$t_1$–subscriber's line, transmitter, and primary winding of the induction coil–s_1–k–Sc–B', thus the relay Tc is also energized, thereby opening the circuit at contacts f and putting out the supervisory lamp Cl.

When the calling subscriber hangs up his receiver, current ceases to flow through the answering relay Ta and its armature b drops down against the armature a, which is held down by current flowing through Sa and the cut-off relay. This closes the contact c and lights the supervisory lamp Al. Pulling the answering plug out of the jack breaks the circuit through the sleeve relay Sa, thereby allowing its armature a to force up the tip relay armature b and hence open the contact c and extinguish the lamp Al. All circuits are now in their normal condition.

22. **Busy Test.**—The contact p, together with contacts h and i in the listening key Lk, are used in connection with the busy test, which operates as follows: The operator tests for a busy multiple jack by throwing the listening key Lk and touching the tip t_1 of the calling plug to the sleeve of the jack desired. The key connects her receiver OR across the calling half of the cord circuit, and also opens contact i and closes contact h; thus a path is established from the tip t_1 of calling plug, through contact h and winding of test relay Tr to earth. If the line is not busy, the ring of the multiple jack will have earth potential, being connected through the cut-off relay winding to the ground side of battery, and the test relay will not be energized. A busy line, however, has battery potential applied to the rings of the jacks due to their connection to the ungrounded side of the battery through the conductor and the sleeve relay Sa of another cord circuit. The touching of the plug tip t_1 to the ring of a busy jack will divert enough current through the test relay Tr to operate it and cause current to flow through the test winding T of the operator's induction coil, thus giving the usual busy click in the operator's receiver OR.

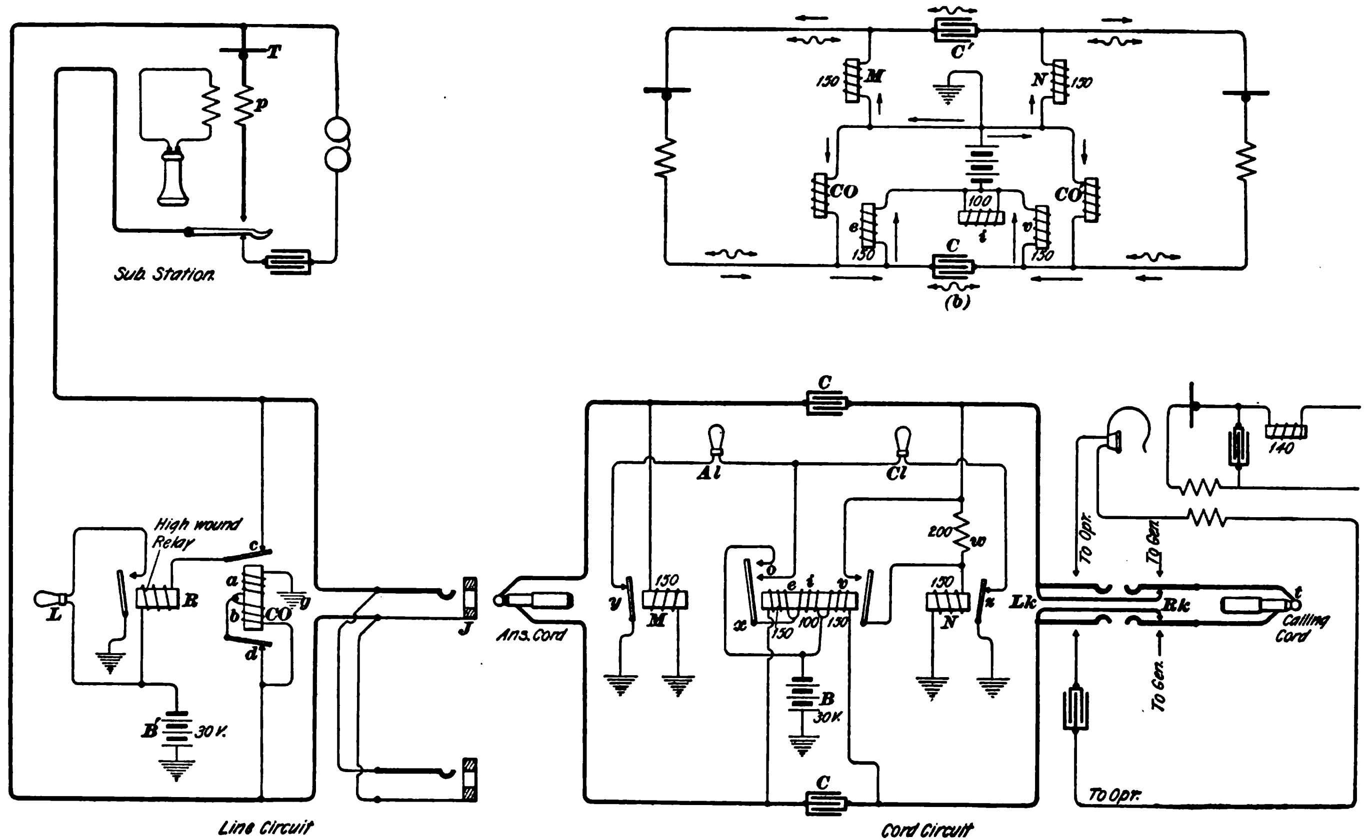

Sub. Station
T
p
(b)
C'
C
M
N
150
CO
CO
e
v
i
100
High wound
Relay
R
L
B'
30 V.
a
b
c
d
y
CO
J
Ans. Cord
Al
Cl
y
M
150
o
e
i
v
x
150
100
130
B
30 V.
200
w
N
z
Lk
Rk
t
Calling
Cord
To Opr.
To Gen.
To Gen.
To Opr.
140
Line Circuit
Cord Circuit

FIG. 6

The opening of the circuit at points *i* and *p* while making the test is necessary in order to disconnect the ground side of the battery that is connected through the tip calling relay *Tc* to *n* and *p*.

23. The extra contacts in the listening key and at *p* also play an important part in the regular act of listening on the calling cord. When the listening key *L k* is thrown, the contact *i* is opened, thus disconnecting the tip circuit *t,–v–l* of the calling plug from the operator's listening circuit. This would not allow the operator to listen in on the calling cord, if it were not for the fact that the relay *Sc* is energized when the calling plug is in a jack, thereby closing the contact *p* and thus connecting the operator's receiver through *j–n–p–l–v* to the tip side of the calling plug.

NORTH CENTRAL-ENERGY SYSTEMS

TWO-WIRE CIRCUIT

24. The latest system used by The North Electric Company up to about 1906 is shown in Fig. 6. The line circuit is of the two-wire variety employing a marginal cut-off relay *C O*, one winding of which is normally short-circuited. Thus, when the subscriber takes his receiver from the hook, current flows through *B′*–ground–*g*–winding *a* of the cut-off relay–armature *d*, which shunts the winding *b*–sleeve side of line–the subscriber's instrument–tip side of line–contact *c* of cut-off relay–line relay *R*. This will operate the line relay and light the line lamp *L*. The cut-off relay is not operated, as the line relay is made of sufficiently high resistance to prevent it. Also the short-circuited portion of the winding reduces the available ampere-turns of the cut-off relay and makes it even more insensitive to the current then flowing.

25. The **cord circuit** is also of the two-wire variety and employs three relays, one of which has three windings. When the answering plug is inserted in the jack *J*, a circuit is closed through *B*–100-ohm and 150-ohm windings *i*, *e* of

the middle relay–sleeve strand of the cord–*d*–winding *a* of the cut-off relay to earth *g*. The current flowing in this circuit, due to its small resistance, is sufficient to operate the cut-off relay *C O*, which clears the line of the line relay *R* and puts out the line lamp *L*. Also, the shunt around the winding *b* of the cut-off relay is removed and the complete winding is connected from the sleeve strand to ground. This current does not operate the middle relay of the cord circuit, as the 100-ohm and 150-ohm windings act in opposition and practically neutralize each other. The answering supervisory relay *M* operates when the subscriber's receiver is off the hook, due to current that flows through *B*–*i*–*e*–sleeve side of circuit–subscriber's transmitter *T*–primary winding *p*–tip side of the circuit–relay *M* to ground; thereby preventing the lighting of the supervisory lamp *A l*.

26. Busy Test.—The operator makes the busy test in the usual manner by first throwing her listening key *L k* and then touching the tip *t* of the calling plug to the ring of the multiple jack of the line desired. If the line is busy, due to there being a plug in some other jack of the desired line, current will be flowing through the winding *e* or *v* to the sleeve strand and cut-off relay of some other line circuit, which is not shown in Fig. 6.

If the line is busy, due only to the subscriber's receiver being off the hook, current will be flowing through the line relay–tip side–subscriber's primary winding of induction coil and transmitter–sleeve side–cut-off relay to ground. If the line is busy for both these reasons, the subscriber's instrument, line, and one supervisory relay form one series-circuit, which is in parallel with both windings of the cut-off relay. The tip *t* of the testing plug has the potential of the ground, because it is connected to ground through the 200-ohm resistance *w* and the supervisory relay *N*, through which no current is now flowing. Touching the tip of this plug to a busy jack puts the resistance *w* and relay *N* in a circuit parallel to either or both the cut-off relay and the subscriber's circuit including a supervisory relay; in any of these three conditions, current

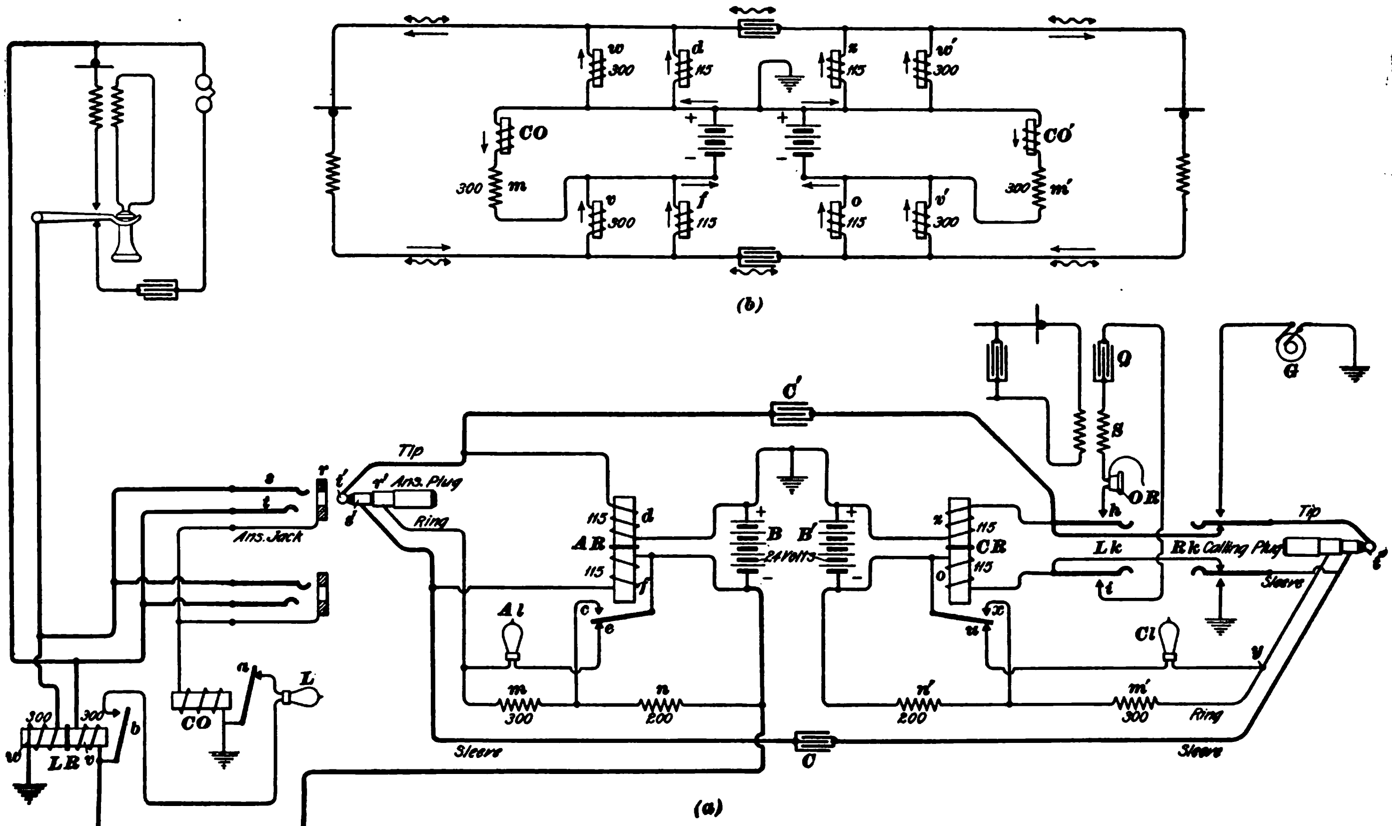
will flow from the sleeve of the jack touched through the 200-ohm resistance *w* and supervisory relay *N* to ground, producing a change in the potential of the tip of the plug that will cause a click in the receiver of the operator making the busy test.

If no plug is in any jack of the line tested and that subscriber's receiver rests on the hook, the sleeve of jack tested will be connected only to the ground through the cut-off relay; and since the tip of the plug is also connected to ground through the resistance *w* and a supervisory relay *N* the jack sleeve and plug tip will both be at ground potential and no busy-test click can be produced. The 200-ohm coil *w* between the calling supervisory relay *N* and the tip strand of the cord prevents the flow of an excessive current to ground when the tip is touched to a busy jack.

27. If the line is not busy, the calling plug is inserted in the jack, thereby allowing enough current to flow through *B*–150-ohm winding *v* of the middle relay–sleeve side of circuit–the winding of the cut-off relay that is not short-circuited–ground to operate the cut-off relay, thereby cutting off the line-signaling apparatus and connecting the two windings of the cut-off relay in series in the circuit just traced, which very firmly holds the cut-off relay closed.

The currents in the two 150-ohm windings *e*, *v* of the middle relay assist each other, and their ampere-turns are sufficient to operate the relay in spite of the opposing ampere-turns in the 100-ohm winding *i*. The closing of this relay does three things. It short-circuits the winding *i* of this relay, thereby causing it to more firmly hold its armature contacts closed; it short-circuits the 200-ohm resistance *w*, thereby allowing the supervisory relay *N* to receive enough current to be held closed; it connects the two supervisory lamps *A l*, *C l* through *o*, *x* to the battery *B*, but they do not now light because the circuit of each is open at the supervisory-relay contacts *y* and *z*.

28. The condition of the circuit during conversation is shown at Fig. 6 (*b*), in which straight arrows represent direct



(b)
w 300
d 115
z 115
w′ 300
CO
CO′
300 m
300 m′
v 300
f 115
o 115
v′ 300
Tip
Ans. Plug
Ring
Ans. Jack
AR
115
B
B′
24 Volts
CR
Lk
Rk Calling Plug
Sleeve
Al
Cl
Q
S
OR
G
C′
C
LB
300
CO
L
Ring
Sleeve
(a)

Fig. 7

current from the battery and the wavy arrows the voice currents that alone pass through the condensers *C*, *C'*.

When either subscriber hangs up his receiver, the corresponding supervisory relay is deprived of current and releases its armature, thereby causing the corresponding supervisory lamp to light. When the plugs are removed from the jacks, all circuits are restored to their normal conditions.

29. This North system employs a 30-volt battery from which current is fed through 150-ohm coils to the line for talking purposes, as shown at Fig. 6 (*b*). These resistances are, of course, inductively wound and form the coils of relays. It is interesting to note that when a single relay, such as this middle relay in the cord circuit, is used to assist in controlling the current for the supervisory lamps, both will light at the same time if the calling plug is in a jack on whose line the receiver has not been removed from the hook and if the answering plug is not in any jack or in a jack on whose line the receiver has not been removed from the hook. This is not necessarily a defect, but is liable to cause false sequences of signals if the regular method of operation is departed from.

THREE-WIRE CIRCUIT

30. In Fig. 7 is shown the North Electric Company's three-wire, central-energy, multiple-switchboard system. It is a well-balanced system and has a natural busy test. The line relay, which has two equal windings, is connected permanently across the line wires with the battery in series with it. This circuit has two similar storage batteries *B B'*.

31. Operation.—When a receiver is taken down, current flows through *B*–ground–*w*–line and subscriber's telephone–*v*–*B*, thereby energizing the line relay *L R* and lighting the line lamp *L*. When the answering plug is inserted in the answering jack, current flows from *B* through one half the winding *d* of the answering supervisory relay *A R*–*t'*–*t*–line and subscriber's telephone–*s*–*s'*–other half *f* of the winding of *A R*–*B*, thereby energizing *A R*, opening contact *e*, and

preventing the lighting of the answering supervisory lamp *A l*. The supervisory relay *A R* is now in parallel with the line relay *L R*; hence, the battery *B* is now connected to each line wire through two inductive paths amounting to about 83 ohms. On account of the inductance of the coils, the increase in the strength of the current produces only a mild click in the waiting subscriber's receiver. Current can also flow through *B*–ground–cut-off relay *C O*–*r*–*r′*–300-ohm resistance *m*–*c*–*B*, thereby operating the cut-off relay, which opens contact *a* and prevents the lighting of the line lamp *L*. The operator answers by closing the listening key, which bridges her head-set across the cord circuit, and she talks to the calling subscriber through the three condensers *C*, *C′*, *Q*.

32. If the line desired is not busy, the plug is inserted in the jack and the ringing generator *G* bridged across the line by closing the ringing key *R k*. Until the called subscriber takes down his receiver, current cannot flow through his line, hence the calling supervisory relay is not energized, contact *x* remains open, and current flows through B'–$\left\{\begin{matrix} u\text{–}Cl \\ n'\text{–}m' \end{matrix}\right\}$–*y*–ring of plug and jack–cut-off relay to ground, thereby energizing the cut-off relay, which prevents the lighting of the line lamp, and allowing the supervisory lamp *C l* to receive enough current to light it in spite of the 500 ohms in parallel with it. When the called subscriber takes down his receiver, the calling supervisory relay *C R* receives current, opens contact *u*, and closes *x*, thereby extinguishing the calling supervisory lamp *C l* and supplying the cut-off relay with current through the 300-ohm resistance *m′*. As the relay *C R* attracts its armature, there is an instant during which the cut-off relay receives current only through *m* and *n* in series, which amounts to 500 ohms. However, this current is sufficient to temporarily prevent the cut-off relay from releasing its armature enough to close its contact, which would, if it happened, allow the line lamp to light. The circuit during conversation is shown at Fig. 7 (*b*). It is a well-balanced circuit.

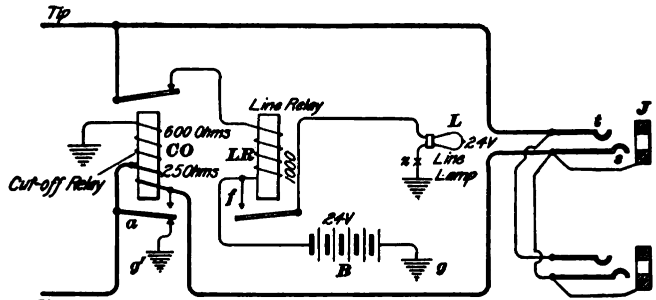
33. Busy Test.—If there is no plug in any jack of the line tested, both the plug tip and jack ring will be at the potential of the ground and no busy-test click is produced, even if a subscriber's receiver is off the hook. If the desired line is busy, due to there being a plug in some jack of the desired line, the path for the current may be traced from $-B$ through the ring strand of a cord circuit and the ring of a jack at some other section–ring of jack tested–tip t''–one winding z of CR to ground terminal of battery B. This current, by altering the potential of the point h, will alter the charge on the condenser Q and produce a busy-test click in a natural manner. Furthermore, as the plug tip is removed, the rapid demagnetization of CR causes it to produce an extra induced current that flows through h–O R–S–Q–i–lower winding o of CR–battery B' to the starting point and produces another click in the operator's receiver. The waiting subscriber also hears the test made as the condensers C, C', being connected to the listening key, are also charged by the extra induced current.

34. With this system, line and cord pilot signals may be used; the lamps are all of the same voltage, because the cut-off relay may be low enough in resistance to allow the use of full-voltage lamps for supervisory signals. This system has proved very successful and satisfactory to subscribers.

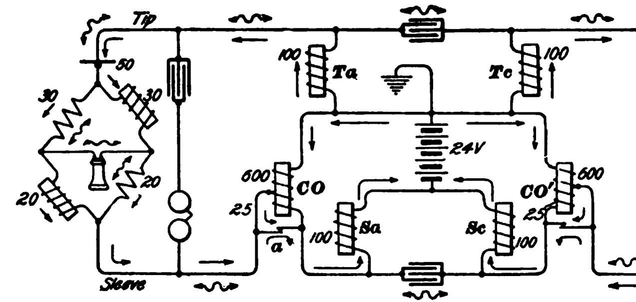
THE DEAN ELECTRIC COMPANY'S CENTRAL-ENERGY SYSTEMS

TWO-WIRE CIRCUIT

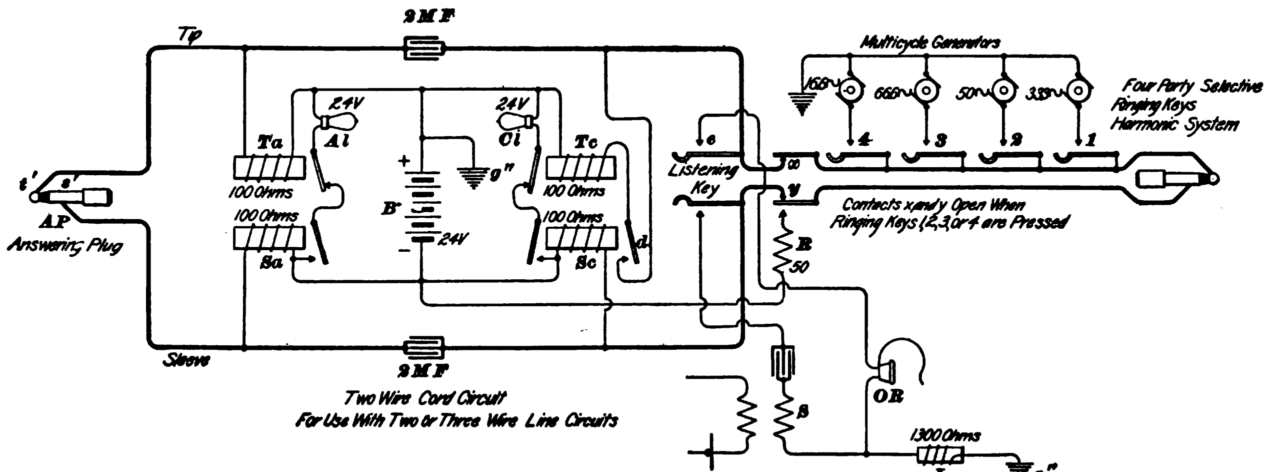
35. Fig. 8 shows the line and cord circuits of The Dean Electric Company's two-wire system, which is now in operation in several independent exchanges. These circuits contain several elements that are similar to other such systems, notably the disposition of the coils when the two parties are connected for conversation. Referring to Fig. 8 (a), it will



Two-Wire Line Circuit
(a)



(c)



Two Wire Cord Circuit
For Use With Two or Three Wire Line Circuits

(b)

FIG. 8

be seen that the cut-off relay CO is so wired that a 25-ohm winding is normally in series with the sleeve side of the line, but when the armature a is attracted this winding is short-circuited so that the talking circuit is clear of all coils.

36. Operation.—When the subscriber removes the receiver from the hook switch, a circuit from the storage battery B is established through the 1,000-ohm winding of the line relay LR–the upper armature of the cut-off relay CO–tip side of line–subscriber's instrument–sleeve side of line and thence through the lower armature a of the cut-off relay to the ground g. The path from the ground side g of the battery through the 600-ohm winding of the cut-off relay CO is shunted by the zero resistance path from g' through the lower armature a so that the cut-off relay does not operate. However, the current through the line relay LR, when the subscriber takes down his receiver, causes its armature to be attracted and light the line lamp L.

37. The feeding of the battery current to the line lamp is exactly the reverse of that usually employed in central-energy systems. Usually the battery is fed through the pilot relay located at the point z, and which is common to the operator's position, thence through the lamps and cable conductors to the line relays. Under these conditions, there is a battery potential on all the line lamps and cable conductors, so that the combined leakage will often be sufficient to cause the pilot relay to become sufficiently magnetized to retain its armature when once pulled up, thus giving a permanent pilot signal. This is usually overcome by a stiffer adjustment of the pilot relay, but at the loss of sensitiveness, which is, of course, necessary, as the pilot relay must operate by the current of either one lamp or a great number of lamps.

In the Dean line circuits, this defect is remedied by feeding the battery to the normally open contacts of the line relays, thereby leaving the cable conductors, line lamps, and line-pilot relay entirely free from battery potential. As the line relays are usually located in the terminal room and

mounted on a non-combustible, open-work, metal rack, the presence of battery potential to which they are continually subjected does not offer much chance for trouble, especially as sufficient fuse protection is provided to insure safety to the wiring. This method of feeding battery to the line lamp through the line relay contacts instead of through the switchboard has been made possible by the modern design of relays. The circuit-changing contacts are insulated from the framework of the relay, so that it is not necessary to consider frame contacts, which, when present, are necessarily connected to the ground side of battery.

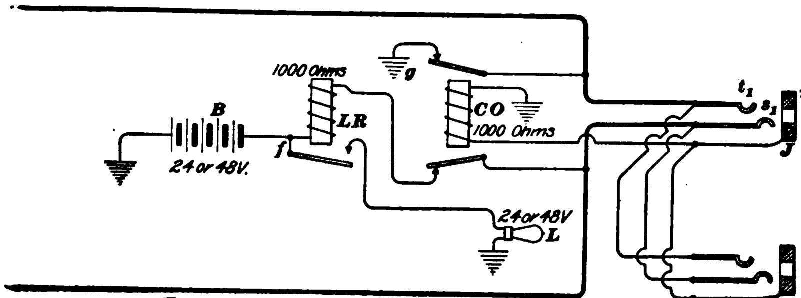
38. When the answering plug *A P* of the two-wire cord circuit is inserted in the answering jack *J* of the two-wire line circuit, a path is established from battery *B′* through the 100-ohm winding of relay *S a*–sleeve side of the plug *A P*–sleeve side of jack *J*–25-ohm winding and armature *a* of relay *C O*–*g′*–ground–*g*–*B′*. As has been previously stated, the 600-ohm winding of relay *C O* is normally shunted by the presence of the ground on the back contact of armature *a*, so that when the plug is inserted, practically all the current flows through the 25-ohm winding, but this is sufficient to energize the relay and cause its armatures to be drawn up. The instant that armature *a* breaks contact with the ground, the 25-ohm and 600-ohm windings act together, as they are then in series; but as soon as the armature *a* is fully drawn up, the 25-ohm winding is short-circuited, leaving the 600-ohm winding to retain the armatures. The upper armature serves to disconnect the line relay *L R* from the tip side of line, thus extinguishing the line lamp *L*. The 25-ohm winding of the cut-off relay *C O* is wound on the armature end and has very little impedance to voice currents, so that, if this relay fails to work when connection is established, it is possible to hold good conversation through it.

The cord circuit, Fig. 8 (*b*), is of the four-relay-and-condenser type, the relays serving as impedance to feed the battery for talking purposes and also to operate the double supervisory lamp signals. The action of the relays is similar

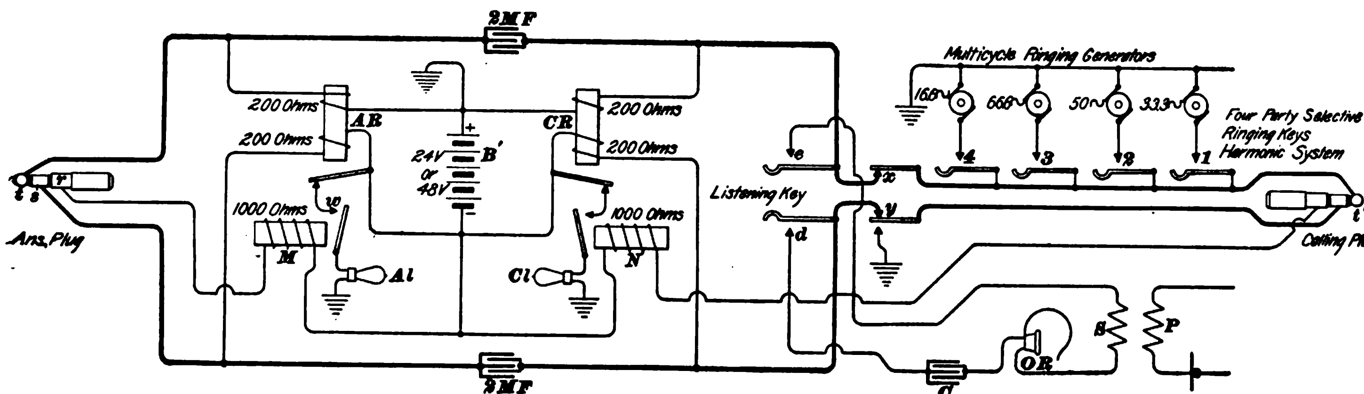
to those of the Stromberg-Carlson and Kellogg Companies' systems. The condition of the one line and cord circuits during a conversation, including the circuits of one subscriber's instrument, are shown at Fig. 8 (*c*).

39. Busy Test.—The sleeve calling relay *Sc* of the cord circuit, Fig. 8 (*b*), has an extra armature *d* that normally disconnects the winding of the tip calling relay *Tc* from the tip strand of the cord circuit. This gives a free tip strand, so that a positive busy test is obtained. When the line is not in use, the sleeve of its jacks have ground potential due to the connection through the 25-ohm winding and armature *a* of the cut-off relay *CO*. However, when the line is busy, due to the presence of a plug in a jack, battery potential is present on all the sleeves due to the connection of the cord circuit battery *B'* through a 100-ohm sleeve supervisory relay, such as *Sa* or *Sc*. Thus, when a test is made by touching the tip of a calling plug to the sleeve of a busy line, current will flow from the negative terminal of the battery through a relay on the sleeve side of some cord circuit–sleeve of busy jack–tip of calling plug used in making the test–contact *e* of listening key–operator's head-receiver *OR*–1,300-ohm retardation coil *I* to ground. This circuit is so arranged that the amount of current flowing through the head-receiver will be just sufficient to give a positive busy test. The retardation of the coil *I* is high enough so that no practical unbalancing of the circuit exists when a listening key is thrown.

40. The **ringing keys** are arranged for selectively ringing four parties bridged across a metallic line circuit. This ringing key is so constructed that when any of its buttons are pressed the two series-contacts *x* and *y* are opened so as to prevent the ringing current from going back through the answering cord. The lever at *y* not only opens the sleeve circuit, but establishes a connection through a 50-ohm non-inductive resistance *R* to battery, so that current will still be supplied from the sleeve side of the line circuit to retain the cut-off relay in its operated condition. This non-inductive



Three Wire Line Circuit
(a)



Three Wire Cord Circuit
(b)

Fig. 9

path also serves as a return circuit for the ringing current, which passes through the battery to the ground side of the multicycle generators. Opposite each generator is marked the frequency of the alternating current it produces.

This complete two-wire system has been designed with the object of having the least possible number of series-contacts in the path of the talking circuit, and in this way reduce the chances of trouble to a minimum. The only series-contacts in the cord circuits are those in the ringing key *x* and *y*, and these are located at the end of the key, so as to be open for inspection when the key shelf is lifted, and so far in practice have given no trouble. In other systems of this type, there are usually two series-contacts on each of the four ringing keys and usually another series-contact in the tip strand of the cord for testing purposes, making a total of nine such contacts, practically all of which are so located as to be very difficult to get at.

THREE-WIRE CIRCUIT

41. The Dean three-wire system, shown in Fig. 9, was originally furnished by The Dean Electric Company to fulfil the requirements of one of the largest independent telephone companies, and is now in operation in at least one exchange. The line circuit, Fig. 9 (*a*), is similar to that of the Bell and Stromberg-Carlson Companies, with the exception of the mechanical construction of the apparatus, windings of the relays, and the wiring of the signaling circuits. The resistances of the relays are made high (1,000 ohms), so as to greatly reduce the flow of current and consequently produce a saving in battery consumption and effectually avoid the disagreeable clicks due to the interruption of the current when a plug is inserted in the line jack. The current for operating the line signals and pilot relays is supplied in the same manner as that described under the Dean Electric Company's two-wire system.

42. The cord circuit shown in Fig. 9 (*b*) employs four relays, two of which are double wound for feeding current

to the line during conversation, while the windings of the other relays are located in the third strand of the cord circuit, and only serve to assist the other relays in controlling the operation of the supervisory lamps. Thus, when the plug is inserted in a jack, current from the battery B' flows through the 1,000-ohm relay M–ring r of plug and ring r_1 of jack and 1,000-ohm winding of cut-off relay CO to the ground side of battery. This operates both relays, cutting off the 1,000-ohm line relay LR and ground connection g, also closing the contact w so as to put the supervisory lamp Al in a condition to receive current. In this position, the line circuit is entirely freed from coils and battery or ground connections, and the supervisory lamp Al is put out by the operation of the relay AR when the subscriber's receiver is removed from the hook switch.

43. Busy Test.—If a line is not busy, the jack-sleeve and plug tip will be at ground potential and no click is produced when the two are touched together. If the line is busy, the negative terminal of the battery is connected through either relay M or N of the cord circuit connected to some jack of this line at some other section–ring of jack tested–tip t'–contact e–upper winding of CR to ground, thus altering the potential of the point e which causes a change in the charge on C and produces a busy-test click in OR. This test is similar to that of the regular Bell three-wire central-energy system.

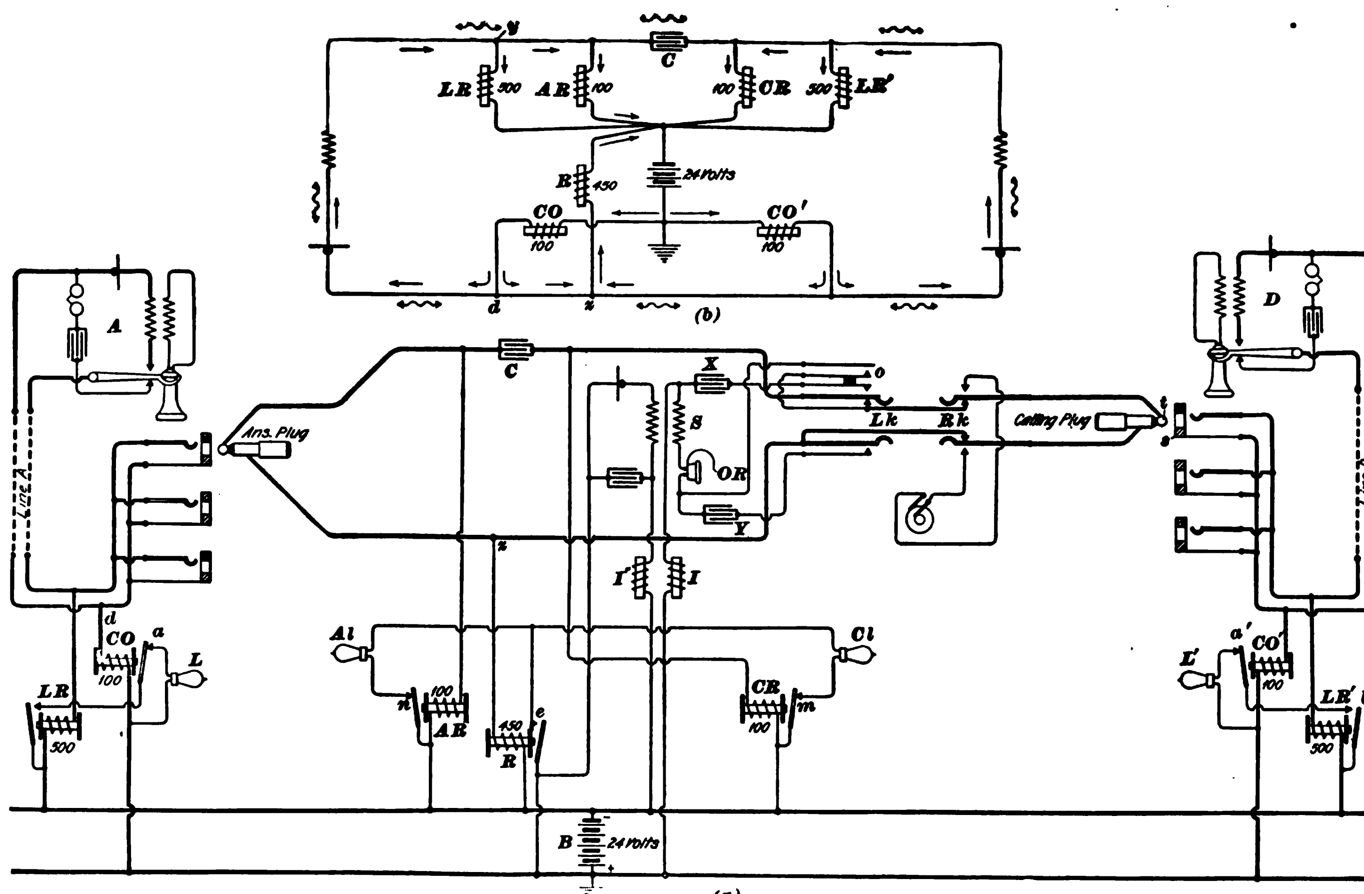
44. The ringing keys are arranged for four-party-line selective ringing, the same as described in connection with Fig. 8. This system is well balanced, as the current for talking is fed through four equal retardation coils forming the windings of relays AR, CR, and the line circuit is furthermore free from any unbalancing conditions.

COMBINED THREE-WIRE LINE AND TWO-WIRE CORD CIRCUIT

45. The combined three-wire line and two-wire cord circuit system of The Dean Electric Company consists of the line circuits shown in Fig. 9 (*a*) and the cord circuit

shown in Fig. 8 (*b*), and at the present time seems to fulfil the greatest number of requirements imposed by the operating companies. The Dean Electric Company has this combined system in operation in a large number of common-battery multiple switchboards. A third strand is provided for the plug-ended long-distance trunks and testing circuits, also in the local half of all toll-to-local cord circuits, so that the cut-off relay can be operated through the third strand of the line circuit and thereby give a clear talking circuit from the subscriber's telephone throughout the switchboard.

The shank or sleeve of the plug of the two-wire cord circuit is made long, as shown in Fig. 8 (*b*), so that when inserted in the three-conductor jacks, Fig. 9 (*a*), the ring spring and sleeve of the latter are electrically connected. The current from battery B', Fig. 8 (*b*), will then flow through the 100-ohm relay Sa–ring r_1 of jack J, Fig. 9 (*a*)–1,000-ohm winding of cut-off relay CO to ground side of battery, thus operating the cut-off relay and the sleeve supervisory relay, as previously described. The 1,000-ohm winding of the cut-off relay CO remains connected from the sleeve side of the cord circuit to ground during conversation, the same as in all two-wire circuits, this condition having no appreciable effect on local service. In other words, this combination system gives the advantage of a saving in maintenance of a two-wire cord circuit over that of a three, and is so designed as to give the best possible conditions for long-distance service and special operating by means of three-wire cords on the few trunks and circuits necessary for the latter service.


LR
AR
C
OR
LR'
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450
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CO'
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A
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Line D
Ans. Plug
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S
OR
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s
I
I'
Al
Cl
CR
R
e
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a
a'
L
L'
b'
B
24 Volts
(a)
Fig. 10

INTERNATIONAL TELEPHONE MANUFACTURING COMPANY'S SYSTEMS

TWO-WIRE CIRCUIT

46. In Fig. 10 is shown the central-energy system said to be used by the International Telephone Manufacturing Company. In series with the sleeve side of the line and the positive terminal of the battery is a 100-ohm cut-off relay *C O*, and in series with the tip side of the line and the negative terminal of the battery is a 500-ohm line relay *L R*.

When the subscriber takes down the receiver, the line relay *L R* operates, but the relay *C O* is adjusted so that it will not operate under this condition; hence the line lamp *L* will light. When the operator inserts the answering plug in the answering jack, the 100-ohm, answering, supervisory relay *A R* is placed in parallel with the 500-ohm relay *L R* and the two in series with the line circuit, say, 100 ohms; the resistance of this circuit will then be $\frac{100 \times 500}{100 + 500} + 100 = 183$ ohms. This circuit is also in parallel with the 450-ohm relay *R*, giving about 130 ohms in series with *C O*. The relays *C O*, *A R*, and *R* will now attract their armatures; hence, the line lamp *L* will go out, the answering supervisory lamp *A l* will not light because its circuit is open at *n*, but the calling supervisory lamp *C l* will light because its circuit is closed at both contacts *e*, *m*.

47. The operator, by closing her listening key *L k*, communicates with the subscriber through the condensers *C*, *X*, *Y*. If the desired line is not busy, the calling plug is inserted in the jack and the ringing key is pressed. Inserting the plug in the jack causes the cut-off relay *C O'* to be energized, which prevents the lighting of the line lamp *L'*. When the called subscriber takes down the receiver, the calling supervisory relay *C R* attracts its armature and the calling supervisory lamp *C l* goes out. Current is furnished for conversation principally through the relays *C O*, *C O'* in the line

circuit and relays AR, CR in the cord circuit. The condition of the circuits during conversation is shown at Fig. 10 (*b*).

48. Busy Test.—The sleeve of the jack is normally at the potential of the ground, or plus terminal of the battery, while the tip of the plug is normally at the potential of the negative terminal of the battery. To avoid a false test, which would result if the positive and negative terminals of the battery had the circuit completed through the plug tip and jack sleeve, the tip of the plug is connected, when the listening key is closed, to ground through contact *o*, receiver OR, secondary S, and the impedance coil I. The impedance of the coil I is high enough to prevent the sudden lowering of the potential of the talking circuit if the line is not busy. If the line is busy, the potential of the jack-sleeve is not quite the same as the ground and enough current flows through s–t–o–OR–S–I to produce the usual busy-test click in the receiver. On account of the high inductance of the coil I, two subscribers talking together will scarcely hear the test when made upon either of their lines.

49. When the subscribers hang up their receivers, the line and supervisory relays release their armatures and both supervisory lamps light. Withdrawing the plugs deenergizes the cut-off relays and restores all circuits to normal condition.

50. Consumption of Current and Energy.—Assuming the resistance of one subscriber's instrument and line circuit to be 100 ohms, what is the ampere-hour and watt-hour consumption for a conversation of 2 minutes duration in the central-energy system of the International Telephone Manufacturing Company? The current and energy consumed during connection or disconnection will not be considered.

The circuit during conversation is shown in Fig. 10 (*b*). First calculate the resistance of one line circuit. The current flows through the cut-off relay CO to d, where it divides into two portions, one through the relay R and the other through the line to point y where it subdivides through LR and AR. The joint resistance of LR and AR is $\frac{500 \times 100}{500 + 100} = 83$ ohms.

To this may be added the resistance of the line circuit giving 183 ohms to point z. Considering both line circuits, the joint resistance to this point is $\frac{183}{2} = 92$ ohms. This resistance is in parallel with R, giving $\frac{92 \times 450}{92 + 450} = 76$ ohms. This resistance is in series with the two cut-off relays, which are in parallel with each other. Their joint resistance is $\frac{100}{2} = 50$ ohms. Hence, the total resistance of two circuits during conversation is $76 + 50 = 126$ ohms. The total current is $\frac{24}{126} = .19$ ampere. This flows for 2 minutes, hence the ampere-minutes are $.19 \times 2 = .38$. This gives $\frac{.38}{60} = .0063$ ampere-hour. The watt-hour consumption is $24 \times .0063 = .0151$ watt-hour.

CENTURY TELEPHONE CONSTRUCTION COMPANY'S SYSTEM

THREE-WIRE LINE AND TWO-WIRE CORD CIRCUIT

51. The well-devised, central-energy, multiple system of the Century Telephone Construction Company is shown in Fig. 11 (*a*), while Fig. 11 (*b*) shows the circuit during a conversation. The arrangement of the operator's transmitter circuit differs slightly from that of all other companies. The transmitter T and primary winding p of the operator's set are connected through a double-wound impedance coil I to the battery terminals, the current through both coils passing in the same direction around the iron core, hence its impedance is large. This primary circuit is connected to the listening key through condensers C_3, C_4. By the use of these two condensers and the double-wound impedance coil, the line circuit is perfectly balanced even during conversations with the operator. The operator's receiver is connected in a closed secondary circuit, as in many subscriber's telephone circuits used by the independent companies. B, B_1, and B_2 are one and the same 24-volt battery.

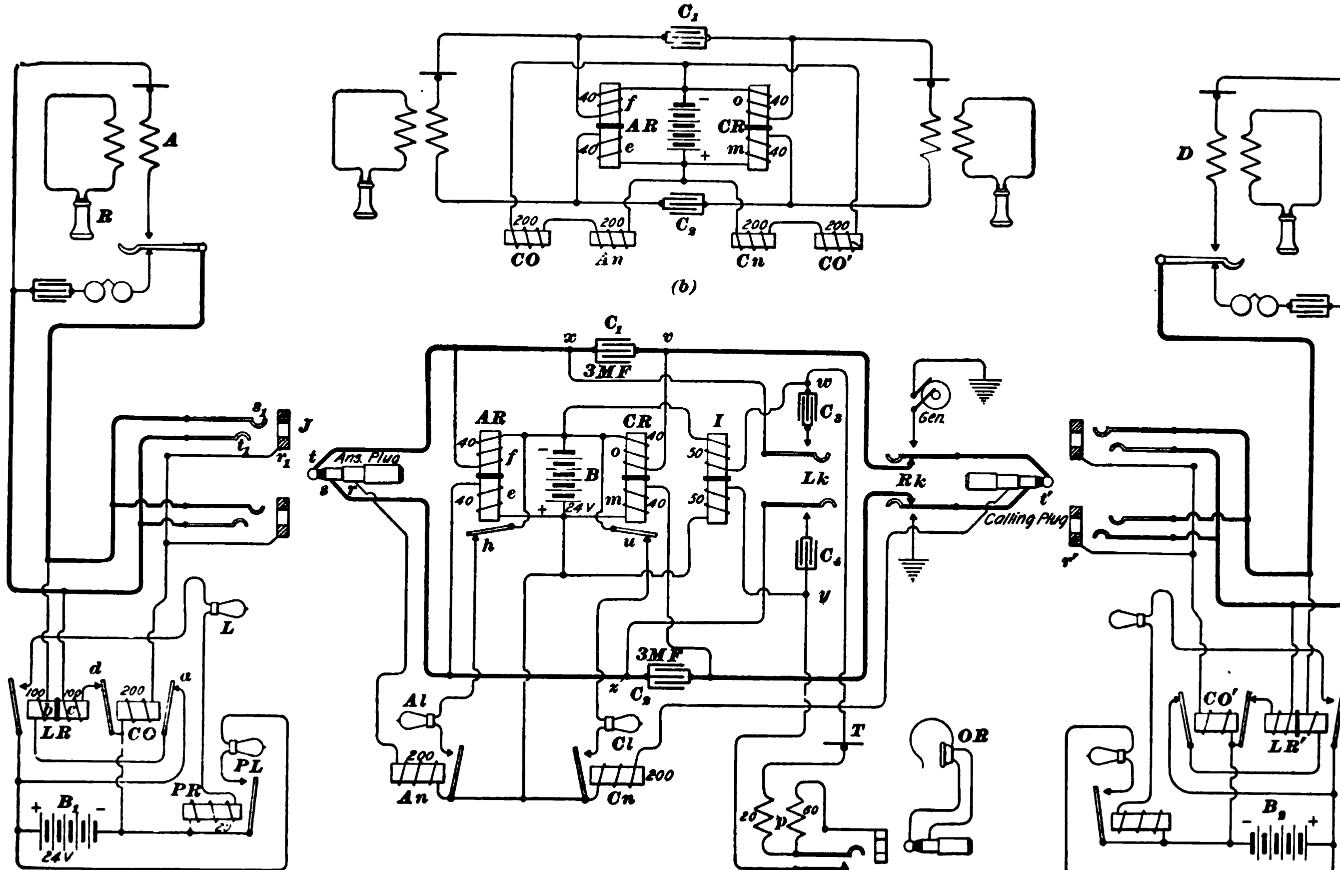

C1
AR
CR
f
e
o
m
C2
CO
An
Cn
CO'
200
40
(b)
A
R
D
x
v
3MF
w
C3
C4
Lk
Rk
Gen.
I
50
B
24 V
h
u
y
z
J
s1
t1
r1
t
s
r
Ans. Plug
Calling Plug
t'
r'
Al
Cl
T
p
20
60
OR
d
a
100
b
c
LR
LR'
L
PL
PR
B1
B2
24V

FIG. 11

52. Operation.—Removing the subscriber's receiver *R* from the hook allows current to flow through B_1–*a*–*b*–subscriber's line and telephone–*c*–*d*, thus energizing the line relay *L R*, which causes the line lamp *L* to light, the line-pilot relay *P R* to close and the line-pilot lamp *P L* to light. The insertion of an answering plug in the answering jack allows current to flow from $+B$ through *e*–*s*–s_1–subscriber's line and telephone–t_1–*t*–*f*, thereby closing the answering supervisory relay *A R*, which, by opening a circuit at *h*, prevents the answering supervisory lamp *A l* from lighting, in spite of the closing of the relay *A n*, which is now in the closed circuit B_1–*A n*–*r*–r_1–*C O*–*B*, B_1 and *B* being the same battery. The cut-off relay opens at *a*, *d* the circuit through both coils on the line relay *L R*. A sound is produced in the subscriber's receiver when a plug is inserted in the jack, as in other systems having line-cut-off relays.

53. The closing of the listening key connects the operator's transmitter *T*, primary coil *p*, and condensers C_3, C_4 across the cord circuit. A variation of the operator's transmitter resistance varies the current in the transmitter circuit, the potential across the points *w*, *y*, the charge on the condensers C_3, C_4, the potential across the points *x*, *z*, and hence allows the operator to talk to the subscriber. A variable current produced by the subscriber's transmitter in the line circuit causes a variation of potential across the points *x*, *z*, and consequently a variable current in the primary winding *p* which induces a variable current in the operator's receiver circuit.

54. Busy Test.—The busy test is made in the usual manner by touching the tip *t'* of the calling plug to the ring *r'* of the jack. If the line is not busy the ring *r'* has the same potential as the negative terminal of the battery B_2 to which it is connected through the cut-off relay *C O'*. The tip *t'* of the plug, which is connected through one winding *o* of the calling supervisory relay *C R* to $-B$, has the same potential as the ring *r'* of the jack, hence no click is produced. However, if the line is busy, due to a plug in

some jack of the line tested, current will be flowing through CO' and hence r' will have a higher, or positive, potential compared with $-B$, and that of the tip t'. Consequently, when t' touches r', current will flow from r' through t'–v–o to $-B$, thereby altering the potential of the point v, which will change the charge in the condensers C_1, C_3, and C_4 and produce in the operator's receiver OR a busy-test click that the waiting subscriber can also hear. The fact that a receiver is off its hook will not alone produce a busy-test click.

55. When the calling plug is inserted in a jack, the relays CO' and Cn are connected in series and both draw up their armatures. This disconnects the line relay LR' from the battery and lights the calling supervisory lamp Cl. The conditions for good ringing of subscribers' bells are excellent because there is no resistance of any kind across the line circuit at the exchange when the ringing key is closed. In many systems, impedance coils or relays are connected across the line circuit while ringing, thereby interfering with good ringing.

When the subscriber takes down his receiver, current flows through both windings of the supervisory relay CR and the subscriber's instrument, which, by opening the circuit at u, puts out the supervisory lamp Cl.

The condition of the circuit during conversation is shown at Fig. 11 (b). The cut-off relay CO and the assisting supervisory relay An are in series during a conversation but are not connected to the line circuit at all. As in many other systems, condensers C_1, C_2 are used to form paths for the voice currents between the answering and calling sides of the cord circuit.

56. When a subscriber hangs up his receiver, the corresponding supervisory relay releases its armature and the corresponding supervisory lamp lights. When a plug is drawn from a jack, the assisting supervisory and cut-off relays are deprived of current, the supervisory lamp goes out, the line relay is connected across the battery, and all circuits are again restored to their normal condition.

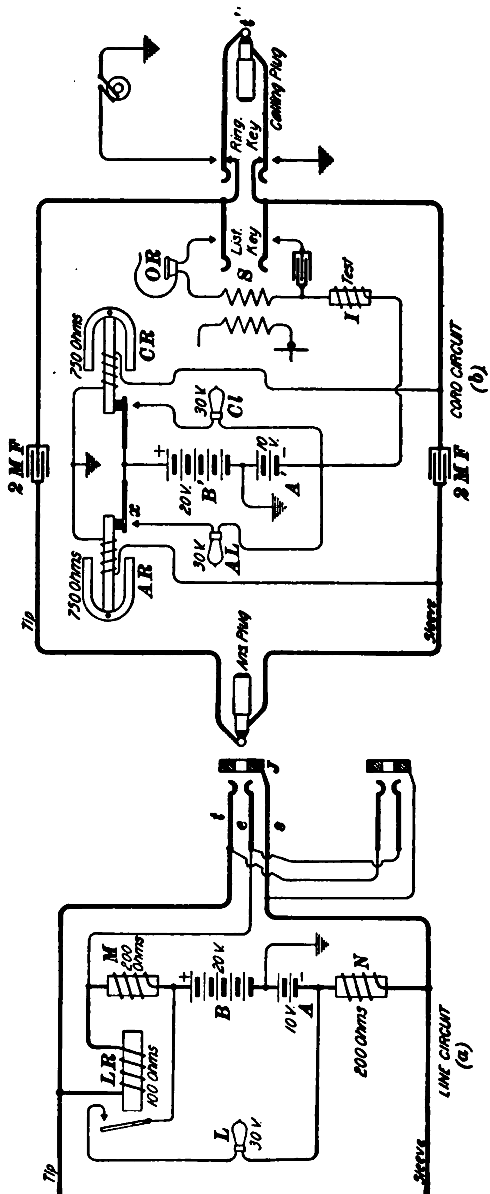
57. The circuit is evenly balanced at all times because the line relay *L R* and supervisory relays *A R* and *C R* are each provided with two equal windings, which are normally connected between each side of the line and the battery terminals. The line relay is cut out during conversations, thereby leaving only one 40-ohm inductive coil between each side of each line and each terminal of a single battery during conversation as shown at Fig. 11 (*b*). The subscribers' transmitters receive enough current, because 40-ohm coils are used where most other systems use at least 75-ohm coils.

EASTERN TELEPHONE MANUFACTURING COMPANY'S SYSTEM

THREE-WIRE LINE AND TWO-WIRE CORD CIRCUIT

58. The circuits shown in Fig. 12 are those employed by the Eastern Telephone Manufacturing Company in its central-energy multiple switchboards. The line circuit, Fig. 12 (*a*) is of the three-wire type, but is so arranged as to supply current direct to line through two retardation coils for serving the subscribers' telephones. When a receiver is removed from the hook switch, a circuit is established from battery *B* through the 200-ohm retardation coil *M*–100-ohm line relay *L R*–tip side of line–subscriber's telephone–sleeve side of line–200-ohm retardation coil *N* to battery *A*, which is in series with *B*; this operates the line relay *L R* and lights the line lamp in the usual way. Instead of using a cut-off relay for disconnecting the line signaling apparatus, the third wire of the line circuit is made to terminate in a third spring *e* in the jack *J*, so that when the answering plug is inserted in the jack, its tip metallically connects this spring with the tip spring *t*, thereby putting a low resistance shunt around the 100-ohm winding of the line relay *L R* and causing it to release its armature.

59. The operation of the supervisory lamps of the cord circuit, Fig. 2 (*b*), depends on the action of polarized relays.



Calling Plug
Ring. Key
List. Key
S
OR
I
Test
CR
750 Ohms
Cl
30 V
2 M F
20 V.
B'
10 V.
A'
x
AL
30 V
AR
750 Ohms
Tip
Sleeve
Ans Plug
CORD CIRCUIT
(b)
J
t
e
s
M
200 Ohms
20 V
B
10 V
A
N
200 Ohms
LR
100 Ohms
L
30 V
LINE CIRCUIT
(a)

FIG. 12

These relays are so arranged that when current flows through their windings in one direction, contacts will be made so as to light the supervisory lamps; while if current flows in the other direction, or when no current is present in the windings, their contacts are open and the supervisory signals are extinguished. This is made possible by the use of two storage batteries with different voltages arranged in series with the ground connection between them. When the answering plug is inserted in jack *J* and the subscriber's telephone is in its normal condition, a circuit will be established from the negative side of the 10-volt battery *A* through the sleeve spring *s* of jack *J*–sleeve side of cord–750-ohm winding of relay *A R*, and thence back to the ground side of battery *A*. This will cause the armature of relay *A R* to close contact *x* and light the supervisory lamp *A L*. However, when the subscriber's receiver is removed from the hook, the 20-volt battery *B* has a circuit established from its positive terminal through the 200-ohm winding *M*–jack-spring *e*–tip of answering plug–tip jack-spring *t*–tip side of line–subscriber's telephone–sleeve side of line–sleeve side *s* of jack *J*–sleeve of cord–750-ohm winding of relay *A R* to the ground side of the 20-volt battery *B*. Part of this current, on the return path through the sleeve side of line, is shunted through the 200-ohm winding of retardation coil *N* and through the 10-volt battery *A* to earth, but this shunt is not sufficient to interfere with the operation of the relay *A R*. The latter relay will now receive positive current instead of negative current, which was present when the subscriber's telephone was in its normal condition, thereby reversing the action of the armature and opening the contact *x*. When the plug is removed, the armature of relay *A R* remains in its normal open condition.

60. Busy Test.—The test for this circuit is obtained in the usual way, but as a battery potential from the 10-volt battery *A* exists on the sleeve of the jack *J*, it is necessary to counterbalance this by connecting an operator's telephone set through a retardation coil *I* to the same side of the 10-volt

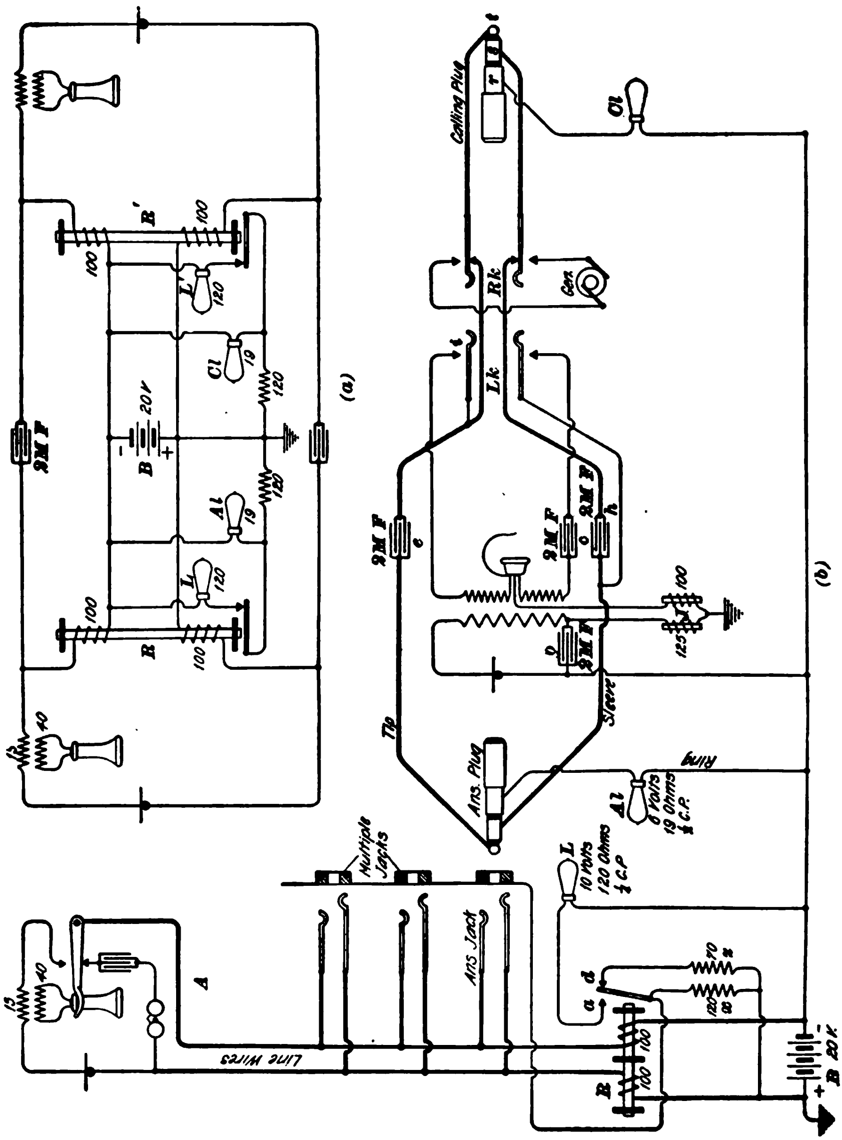

(a)
R
R'
L
L'
Cl
Al
B 20 V
2 M F
(b)
Calling Plug
Rk
Lk
Gen.
Tip
Sleeve
Ring
Ans. Plug
Multiple Jacks
Ans. Jack
Line Wires
A
L 10 Volts 120 Ohms ½ C.P.
Al 6 Volts 19 Ohms ½ C.P.
B 20 V

FIG. 18

battery A. If the line is not busy, no click can be heard in the operator's receiver OR, when the tip t' of the calling plug is touched against the sleeve of the jack J, but if the line is busy, the positive side of the 20-volt battery B associated with the busy line will be connected through the subscriber's telephone and line, sleeve of jack and the 750-ohm winding of relay AR, in the cord circuit whose plug is in the busy jack, to ground. Thus, when the tip of the calling plug is touched to the sleeve of the busy jack J, the latter has a potential that differs somewhat from that of the negative terminal of A' or A and will cause a flow of current through the tip of calling plug used in making the test–operator's receiver OR–secondary S of the induction coil–test retardation coil I–10-volt battery A' to the ground side of the 20-volt battery B' and a busy-test click is produced in the operator's receiver OR.

61. This circuit is somewhat different than the usual design of multiple-switchboard circuits and seems to give good service where used, but, like all circuits in which current is supplied from the battery direct to the line through retardation windings, is devoid of flexibility. There has been considerable reluctance on the part of operating companies to use a polarized device as a relay, but, as this is simply a matter of proper mechanical and electrical designing of telephone apparatus, it should not be considered a serious defect in a circuit.

STERLING ELECTRIC COMPANY'S SYSTEMS

ONE-RELAY CIRCUIT

62. The central-energy systems of the Sterling Electric Company have three conductors in the line and cord circuits. The connections of the one-relay multiple-switchboard system said to have been installed by the Sterling Electric Company in many places are shown in Fig. 13 (*b*). In one place, the switchboard had a capacity of 1,000 lines and in

another 1,500 lines. This is a **one-relay system,** that is, there is for each subscriber's line but one relay controlling all the signals for connections and disconnections to that line. It is of the impedance-coil, battery-supply, and condenser-transmission type in which the impedance coils are permanently connected to the line wires and serve as magnets for the signal controlling relays, and in which the condensers are connected in the talking conductors of the cord circuits. The common battery is composed of ten storage battery cells of about 2 volts each or 20 volts for the whole battery. The circuit of the subscriber's telephone shown at A is the one used in the Sterling instruments, although any other standard central-energy instrument circuit is equally adaptable to this switchboard system.

63. The line relay R has two coils of 100 ohms each on the same core. Through these two coils, the battery current is supplied to the line and to the transmitter in the subscriber's telephone when the receiver is off the hook. Normally, there is no flow of current, the circuit being open at the condenser in the subscriber's bell circuit. Thus the relay R is always under the control of the party at the subscriber's telephone. The relay has two contacts a, d, one d normally closed, the other a normally open. The resistances x, z are connected. respectively, to the armature and to the normally closed contact of the relay, the other terminal of each being connected to ground. x has a resistance of 120 ohms and z 65 to 70 ohms. The armature of the relay is connected to the test rings of all the jacks of that line. The line lamp L and the supervisory lamps $A\,l, C\,l$ have one terminal each permanently connected to the ungrounded terminal of the battery B; the other terminal of L is connected to the normally open-contact point a of the relay R and the other terminal of $A\,l, C\,l$ is connected to the ring contacts of the plugs. The line lamp L is designed to give a good signal with 10 volts across its terminals, and its resistance, when full current is flowing, is about 120 ohms. It gives a light equivalent to about $\frac{1}{4}$ candlepower. The supervisory lamps $A\,l, C\,l$ are

designed, on the other hand, to give a good signal with 6 volts across their terminals. The resistance of each lamp, when full current is flowing, is about 19 ohms and each gives a light equivalent to about $\frac{1}{2}$ candlepower. In general, the line lamp is of low candlepower, high resistance, and high voltage while the supervisory lamp is of high candlepower, low-resistance, and low voltage.

64. Operation.—Assume that the subscriber at station *A* removes his telephone receiver from its hook. The relay *R* is energized and its armature closes the normally open contact point *a* and the lamp *L* lights, receiving current through a circuit including the battery *B* and the 120-ohm coil *x*. As the lamp and coil have each a resistance of 120 ohms and the total voltage of the battery is 20, the drop in potential through the lamp is 10 volts, this being the voltage required for the lamp to become a good signal. The operator then inserts an answering plug in the answering jack of the line calling. The supervisory lamp *A l* becomes then a shunt circuit about the lamp *L* in the before-mentioned circuit. On account of the much lower resistance of lamp *A l*, the line lamp *L* is deprived of the greater part of the current previously flowing through it so that *L* no longer glows as a signal. Moreover *A l* does not receive sufficient current to cause it to glow because the flow of current is limited by the comparatively high resistance of the 120-ohm coil *x*, which is now in the same circuit with it. Should the subscriber at station *A* replace his receiver on the hook switch, the relay armature will fall back, opening the circuit at *a* through line lamp *L* and closing at *d* the circuit containing the 70-ohm resistance coil *z*. The 120-ohm coil is now in parallel with the 70-ohm coil, so that the joint resistance in series with the lamp *A l* is but 44 ohms. The current flowing is then sufficient to cause *A l* to glow, thus giving a disconnect signal.

65. The diagram shows the usual operator's equipment, the transmitter being supplied with current from the common battery *B* through a 125-ohm impedance coil *J*. The secondary of the induction coil is split into two equal coils, as is also

the receiver winding. A combination ringing and listening key *L k*, *R k*, with connections as shown, is a part of the equipment of each pair of connecting cords.

There is considerable waste of electrical energy from the calling generator on account of the 200-ohm relay *R* and the battery that are in series and permanently bridged across the line circuit. To reduce this loss to a minimum, the relay magnets are made of high impedance by providing them with extra heavy iron cores. When the operator closes the ringing key *R k*, the ringing generator is connected across the tip and sleeve strands *t* and *s*, respectively, of the calling plug and line of the subscriber to be called. When the listening key is closed, the receiver, secondary winding of the induction coil, and the condensers *c*, *e* are connected in series across the tip and sleeve strands of the answering plug. If necessary, the operator can also communicate with the subscriber called by closing the listening key. The receiver and the condensers *c*, *h* are then connected in series across the tip and sleeve strands of the calling plug. The condenser *c* is necessary to prevent waste of the battery current in the operator's receiver circuit. There is a ground connection from the center of the coil in the operator's receiver through a 100-ohm impedance coil *J*, called a test coil.

66. Busy Test.—The conditions for a busy test are that either the subscriber has removed his receiver from its hook or that the operator has inserted a plug in a jack of the line. Suppose that the subscriber's receiver has been removed from its hook and that the operator touches the tip *t* of a calling plug to the ring contact of any jack of a busy line. Current from the positive pole of the battery *B* flows through the armature and front contact of the relay of that line through the line lamp of the busy line, back to the battery. On account of the drop in potential, due to the current that flows through the 120-ohm coil, the relay armature and also the ring contact of the busy jack, which is connected directly to the relay armature, will be at a different potential than the grounded end of the battery. Therefore, when the tip of the calling

plug is touched to the ring contact of a busy jack, current will flow through the tip strand of the cord circuit–contact *i* in listening key–half of operator's secondary and receiver coils–impedance coil *J* to the ground, thus producing a click in the receiver.

This may be looked at in another way, as follows: Current flows from the positive terminal of the battery through two parallel circuits; namely, through the 120-ohm resistance coil and through the ground, impedance coil *J*, half of the operator's receiver circuit, contact *i*, tip *t* of calling plug, and ring of busy jack to the armature of the busy-line relay; there the two currents unite and flow through the line lamp of the busy line back to the battery. When the line is not busy, the relay armature is not attracted, the line lamp circuit is open, the tip of the calling plug and the ring of the idle jack tested are at ground potential, and hence no click is produced in the operator's receiver. If the line is busy due to a plug being in some jack, but the subscriber's receiver is on the hook, the test is practically the same, for the 70-ohm and 120-ohm coils, which are in parallel, and the supervisory lamp then take the place of the 120-ohm coil and the line lamp in the above explanation.

67. Fig. 13 (*a*) shows simply the battery supply and transmission circuits when two subscribers are conversing. The two coils on each of the relays *R*, *R'* are wound on the same core in such a direction as to assist each other in magnetizing the core and to offer the greatest inductive opposition, or impedance, to any variable current, such as the voice current, that may tend to flow through either relay and the battery from one line wire to the other. At the same time, their resistance is low enough to allow as strong a steady current as is desired to flow from the battery *B* through the line wires, the primary winding of the induction coil, and the transmitter in each subscriber's telephone set. The subscriber's receiver is connected in series with the secondary of the induction coil in a permanently closed local circuit. The two condensers connected with the two line circuits

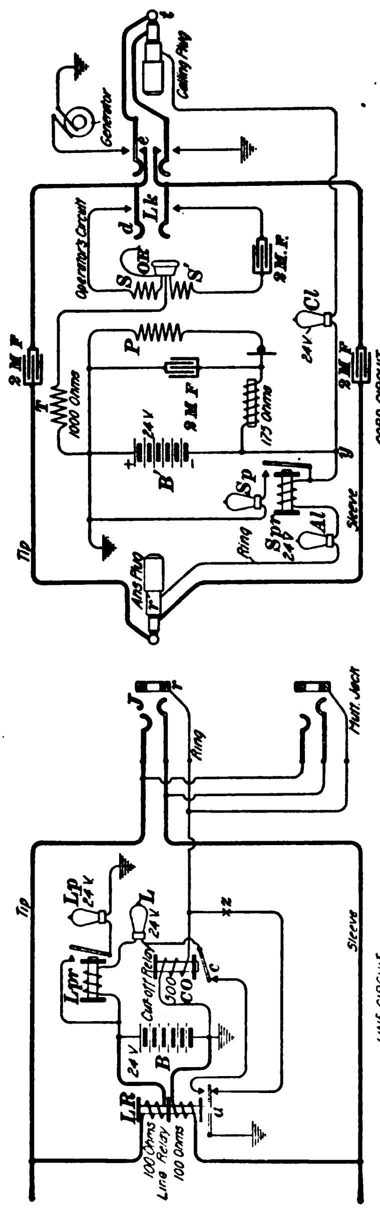


FIG. 14

readily permit the voice currents to pass from one line to the other. This diagram also shows the large current required to keep the supervisory lamps dim during conversations.

The current consumed in this system during conversation is enormous when compared with other modern systems, so much so as to greatly offset any advantage due to simplicity. There is no chance to insert line-pilot and supervisory-pilot lamps and a common night alarm, as in other systems, which is a very bad defect in respect to operating. The lamps are all lower voltage than the battery and also are of two voltages. This is liable to lead to mistakes and consequent burning out of lamps. The later two-relay Sterling system eliminates these defects, and from the operating standpoint combines simplicity and excellence.

TWO-RELAY CIRCUIT

68. The circuit shown in Fig. 14 illustrates the latest circuits employed by

the Sterling Electric Company in its central-energy multiple switchboards. The line circuit differs from that of the one-relay system, in that a cut-off relay *C O* is provided in the third strand of the circuit for extinguishing the line lamp instead of the combination of shunts, as employed in the older system. This naturally reduces the current consumption and does away with lamps of different voltages, both items being serious defects in the one-relay system.

The current for talking is fed through the two windings of the line relay *L R*, so that each cord circuit contains nothing but the condensers for metallically separating the two connected subscribers and the two supervisory lamps in the third strand. There is one supervisory pilot relay per operator's position. The current for lighting the lamps is controlled by the line relays through the third strand of the line and cord circuits.

69. Operation.—When a subscriber removes his receiver from the hook switch, a circuit is established from battery *B* through the upper winding of the line relay *L R*–tip side of line–subscriber's telephone–sleeve side of line–lower winding of line relay *L R* to ground side of battery. The armature *a* is attracted thereby completing a circuit from battery *B* through the line-pilot relay *L p r*–the line lamp *L*–armatures *c*, *a* to ground, thereby lighting the line lamp *L*. Unlike the Sterling Electric Company's one relay system, pilot relays can be inserted at *L p r* in the line circuit, as well as at *S p r* in the cord circuit for operating the usual line-pilot lamp *L p* and supervisory-pilot lamp *S p*, and through them the night-alarm bell whose circuit, being quite simple, is not shown here. When shunted lamps, as in the one-relay system, are used, it is impossible to insert these pilot signals.

The insertion of the answering plug in the line jack allows current to flow through *B'*–ground–500-ohm winding of the cut-off relay *C O*–ring *r* of jack–ring *r'* of plug–answering-supervisory lamp *A l*–supervisory-pilot relay *S p r*–*y*–*B'*. The cut-off relay is thus operated, opening the

contact *c* and extinguishing the line lamp *L*. The supervisory lamp *A l* does not light as the 500-ohm winding of the cut-off relay makes the current too small. However, when the subscriber hangs up his receiver and the armature *a* of the line relay *L R* is released, a low-resistance path is established through *B′*-ground-*a*-*z*-*r*-*r′*-*A l*-*S p* *r*-*y*-*B′*, thereby lighting the lamp *A l*. When the plug is removed from the jack, the circuit is restored to its normal condition.

70. The **busy test** is obtained, in the usual way, by touching the tip *t* of the calling plug to the ring of the jack, which, when busy, has battery potential, that is, the potential of the ungrounded side of the battery, thus allowing current to flow from $-B'$ through the supervisory lamp of some cord circuit whose plug happens to be inserted in some jack of this line-ring of jack tested-tip *t*-*e*-*d*-upper half *S* of the secondary winding of the induction coil-one half of the winding of the receiver *O R*-1,000-ohm test resistance *T* to ground side of battery; this flow of current is sufficient to give the usual busy test. However, from the time a calling plug is inserted in a subscriber's line until the subscriber has answered, the rings of the jacks have ground potential due to the connection of the ring *r* through *z* and the armature *a* to ground, so that no busy test is given during this time. This is a very serious defect and cannot be overcome without remodeling the circuit. In several installations where this system is in use, a low resistance has been inserted in the third strand of the line circuit at the point *z*, so as to allow a slight potential to exist on the sleeves of the jacks, thereby obtaining a faint busy test. The resistance at *z* cannot be made very great, as it will then prevent the supervisory lamp from lighting to its full brilliancy when a disconnection is desired.

71. While this system is of the three-wire variety, it does not have the flexibility of the other three-wire systems, due to the fact that the line relay *L R* is permanently connected to the line circuit, thereby serving not only as a shunt to the ringing current used in calling a subscriber,

but prevents clear talking from the subscriber's instrument to the jack-terminals. These two defects apply, however, to any system having line relays or coils permanently connected between each line wire and the battery terminals.

CENTRAL-ENERGY MAIN AND BRANCH EXCHANGES

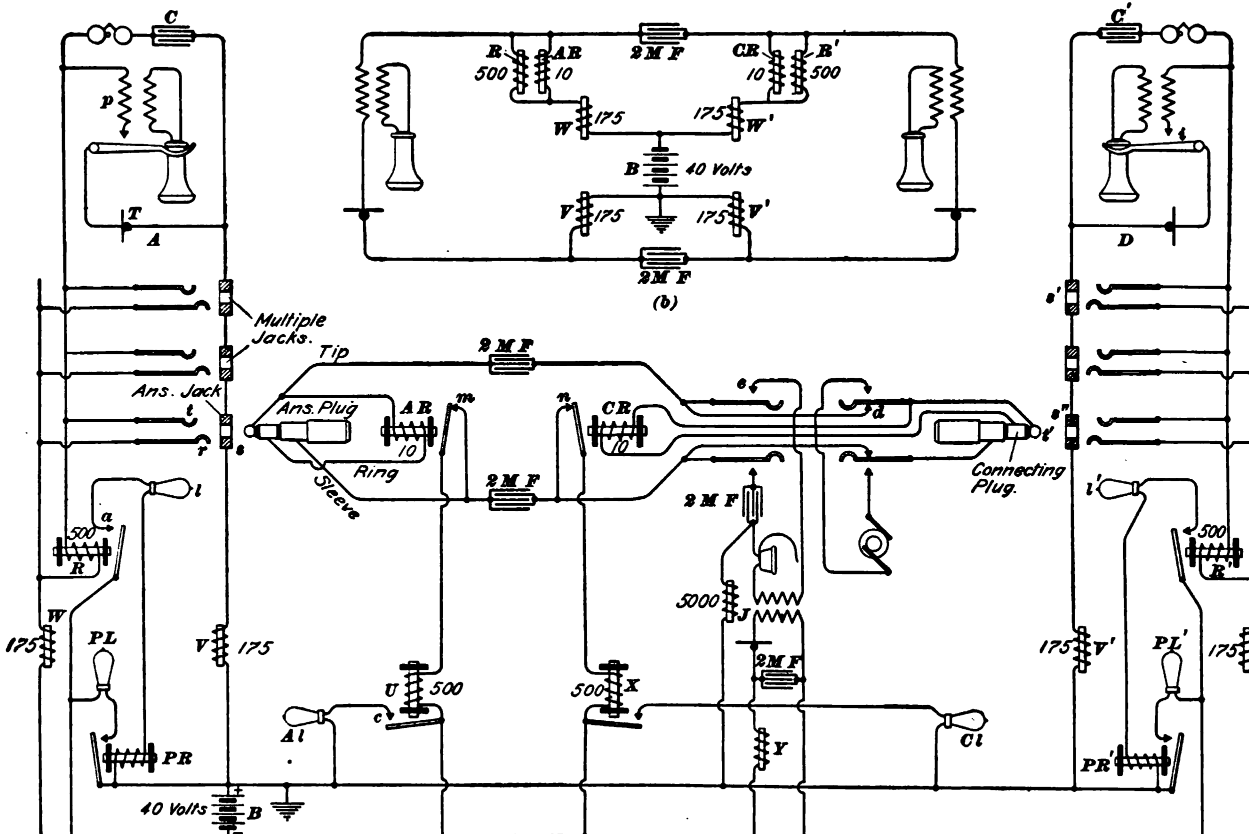
CENTRAL-ENERGY SYSTEMS

AMERICAN ELECTRIC TELEPHONE COMPANY'S SYSTEMS

THREE-WIRE SYSTEM

1. A diagram of the central-energy multiple-switchboard system installed in several large exchanges by the American Electric Telephone Company is shown in Fig. 1. It is of the impedance-coil, battery-supply, and condenser-transmission type. One impedance coil *V* is permanently connected in series with one terminal of the common battery and one line wire, and the other impedance coil *W* is permanently connected in series with the other terminal of the common battery, the line relay *R*, and the other line wire. The line relay is of comparatively high resistance, while the supervisory relay *A R* has a comparatively low resistance and is located in the cord connecting circuit, but so arranged that, when the plug with which it is associated is inserted in a spring jack of a line, its coil short-circuits the coil of the line relay. Condensers are connected in the talking conductors of the cord circuit.

2. Fig. 1 (*b*) shows the battery-supply and transmission circuits between two subscribers' stations when connected together through the switchboard during a conversation. A


C
p
T
A
R
AR
500
10
2 M F
CR
R'
W
175
W'
B
40 Volts
V
V'
(b)
C'
D
Multiple Jacks.
Tip
Ans. Jack
t
r
s
Ans. Plug
AR
10
m
n
CR
Ring
Sleeve
e
d
s'
s"
t'
Connecting Plug.
l
a
500
R
l'
R'
2 M F
5000
J
W
175
PL
V
U
500
X
Y
PL'
Al
c
Cl
PR
PR'
40 Volts
B

(a)

FIG. 1

10-ohm supervisory relay is in shunt with a 500-ohm line relay. In later exchanges, this latter relay has been wound to a resistance of only 300 ohms.

In Fig. 1 (*a*) is shown two subscribers' stations and lines with the central-office equipment, and a complete cord circuit in the usual conventional manner. The common battery *B* is composed of twenty storage-battery cells of about 2 volts each, or 40 volts for the whole battery. The equipment and arrangement of circuits in a subscriber's instrument is shown at *A*. The line jacks have each two spring contacts *t*, *r* and a sleeve *s* that are adapted to register, respectively, with the tip, ring, and sleeve of a plug. The short springs *t* and the sleeves *s* of the jacks are connected to the line wires directly and the long springs *r* are connected to a wire running to the coil of the line relay *R* and the impedance coil *W*. The line signal lamp *l* is in a local-battery circuit including the normally open switch contact *a* of the relay *R*. A pilot lamp *PL* is controlled by a pilot relay *PR* whose coil is of low resistance, approximately 3 to 5 ohms, and included in the common-battery supply wire to all the line lamps for one operator's position on the board.

The tips of the answering and connecting plugs are joined by a conductor including a condenser, as are also the sleeves of the plugs, and there is included the usual listening and ringing keys associated with the calling, or, as it is also termed, the *connecting plug*. The answering supervisory relay *AR* has a resistance of only 10 ohms and one terminal is connected to the tip and the other to the ring of the answering plug. The supervisory lamp *Al* is in a local-battery circuit including the normally open switch contact *c* of the relay *U*, while the coil of the relay *U* is connected from a battery wire, through the normally closed contact *m* of the supervisory relay *AR* to the sleeve strand of the cord circuit. The lamp *Al* and relays *AR* and *U* are associated with that part of the circuit connected to the answering plug. Corresponding lamp and relays are associated in the same manner with the connecting plug.

3. It might seem that this circuit could be simplified by connecting the lamps *A l* and *C l*, in place of the relays *U* and *X*, which would require less current and do away with two relays. Such an arrangement would require a lamp that would light when in series with the 175-ohm coil *V*, that is, a lamp of lower voltage than the battery, and different from the voltage of the line lamp; these are practical objections. Furthermore, a lamp has no inductance; hence, one side of the line would be connected directly to the battery merely through a non-inductive resistance, which would tend to make the circuit noisy, especially while connections are being made. The use of the 500-ohm relays *U*, *X* avoids this objection.

4. In the operator's individual equipment, there is the usual transmitter and primary circuit including an impedance coil *Y* and a secondary circuit including the head-receiver and a condenser, with a ground connection to the receiver through a 5,000-ohm impedance coil *J* for use in making the busy test. When the listening key is closed, the tip of the calling plug is connected to the ground side of the battery through contacts *d* and *e*, the operator's telephone and the test coil *J*, and furthermore the sleeves of the line jacks are at the same potential as the ground side of the battery except when current is flowing through the impedance coil *V'* due to the line being busy.

5. Operation.—To explain the operation of the system, we will assume that the subscriber at station *A* removes his receiver from the hook to call the central office. The line lamp *l* lights, due to the energization of the relay *R*, current passing from the positive terminal of the battery through *V-T-p-R-W* to the negative terminal of the battery. An operator then inserts an answering plug in the answering jack of the line, whereupon the light *l* goes out, its circuit being opened at *a* since the armature of the line relay *R* is released, because the coil of the 500-ohm relay *R* is now shunted by the 10-ohm coil of the supervisory relay *A R*, which becomes energized by the current passing through *B-V-T-p-t-A R-r-W-B*. The supervisory relay *A R* therefore draws up its

armature, thus opening the circuit at *m* through the relay *U*. Now, should the subscriber at station *A* replace his receiver on the hook, current from the battery, on account of the condenser *C*, will cease to flow through his line circuit in which the two impedance coils *W*, *V* and the supervisory relay *A R* are included. Consequently, the relay *A R* will release its armature, thereby closing at *m* the circuit through *B*–*V*–*s*–sleeve strand of the answering plug circuit–contact *m*–relay *U*, which, in turn, closes a local circuit at *c* and hence the answering supervisory lamp *A l* will light as a disconnect signal. In using the connecting plug to complete the connection with a called subscriber, the same relative conditions will occur to effect the operation of the supervisory signal associated therewith as have just been described with reference to the answering plug.

6. Busy Test.—The operator will test a line called in the usual way; that is, by touching the tip of the connecting plug to the sleeve of jack of that line while her listening key is closed; if the line is busy, she will hear in her head-telephone the usual busy click. The conditions under which an operator testing a line will receive the busy click are either that the subscriber wanted, say *D*, has removed his receiver from the hook, or that any operator has inserted a plug into any spring jack of that line.

In Fig. 2 (*a*) is shown the portions of the circuit in which current flows when a test is made on a line that is busy due to the receiver at the subscriber's station being off the hook. The arrows show the direction of the currents. When the tip t' of the connecting plug touches s', the operator's circuit h–J–e–d–s' shunts the circuit h–V'–s', and hence the current is divided at *h*, part flowing through the operator's circuit, thereby producing the busy-test click in her receiver. At the point s', the two currents unite and flow through the subscriber's instrument, the line relay R', and the impedance coil W' to the negative terminal of the battery.

In Fig. 2 (*b*) is shown the busy-test circuit when the line is busy due to a plug p' having been inserted in some jack of

that line at another section, assuming that the subscriber has not yet lifted the receiver off the hook. In this case, the operator's circuit h–J–e–d–s'–s'' shunts the circuit h–V'–s''. Hence, current is diverted through the operator's circuit,

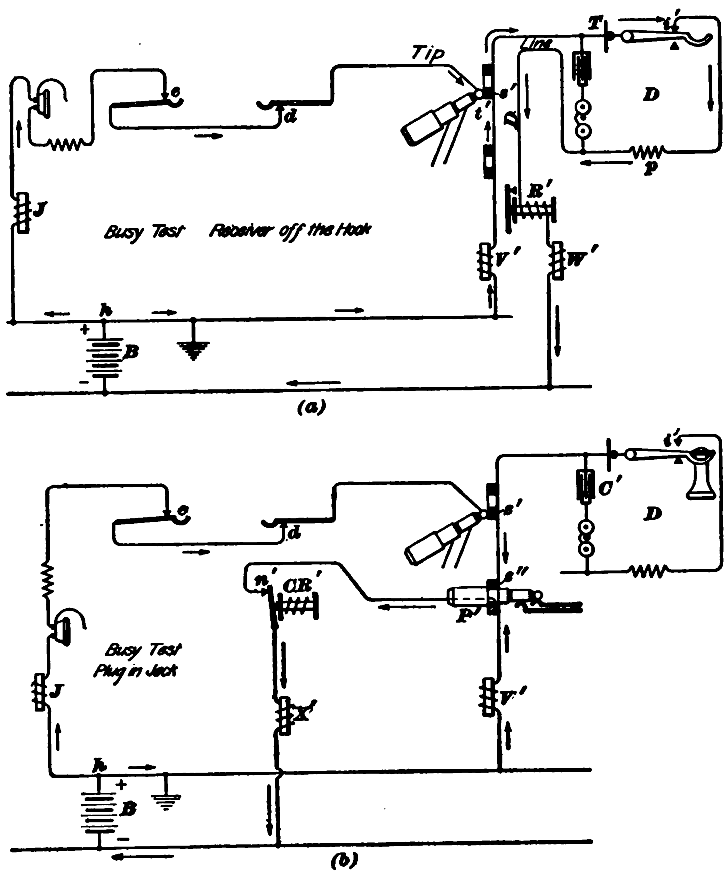


FIG. 2

thereby producing the busy-test click, and the united currents flow through s''–sleeve of plug P'–contact n'–relay X' to the negative pole of the battery. No current can flow through the subscriber's instrument for the circuit is open to a direct current at the condenser C' and also at i'.

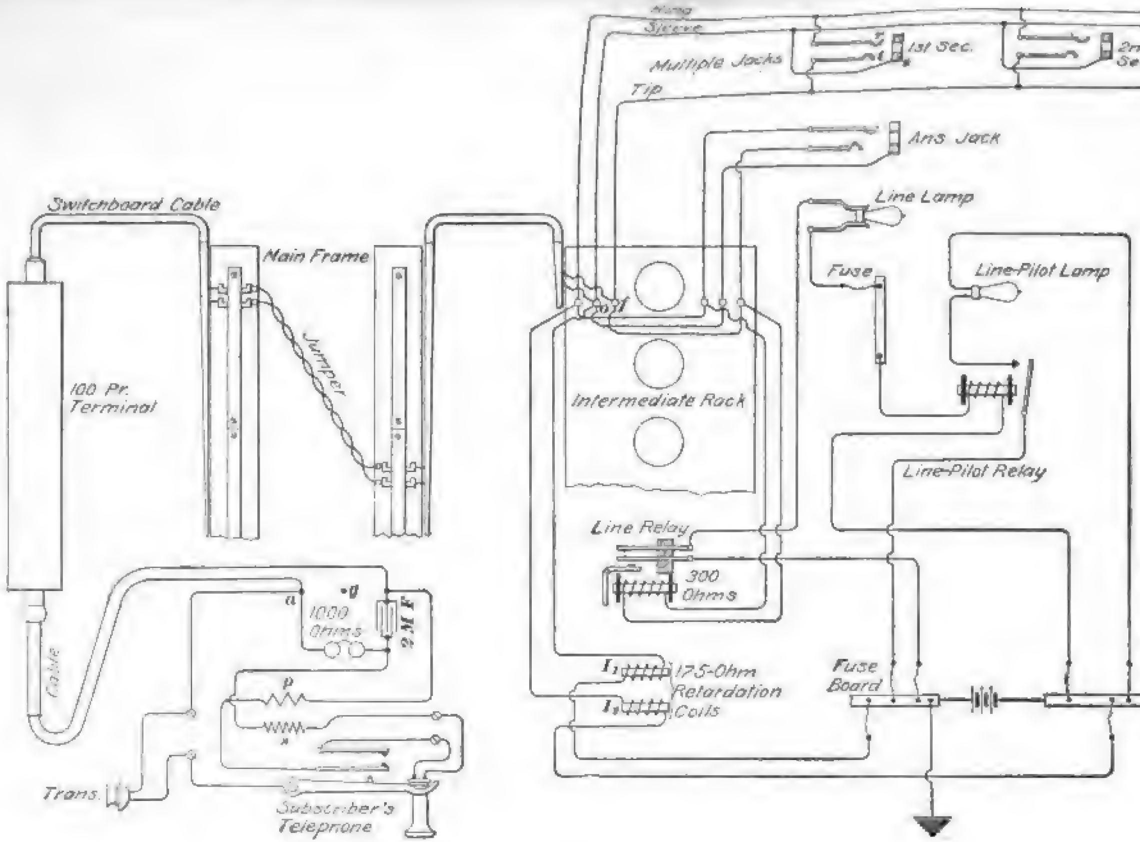

Ring
Sleeve
Multiple Jacks
Tip
1st Sec.
2nd Sec.
Ans Jack
Line Lamp
Line-Pilot Lamp
Fuse
Line-Pilot Relay
Switchboard Cable
Main Frame
Jumper
100 Pr. Terminal
Intermediate Rack
Line Relay
300 Ohms
I_1
I_2
175-Ohm Retardation Coils
Fuse Board
Cable
a
g
1000 Ohms
2 M F
p
Trans.
Subscriber's Telephone

Fig. 3

Therefore, whether a line is busy due to a subscriber's receiver being off the hook or due to a plug being in a jack at any section, current will be flowing through the impedance coil V', and, according to the short explanation usually given, will raise the potential of the sleeves of all the jacks of the busy line and cause a current to flow to ground through the operator's receiver when the tip of a plug is touched to the contact of a jack of a busy line.

7. If the line is not busy, the connecting plug, Fig. 1, is inserted in the jack and the 10-ohm calling supervisory relay CR shunts the line relay R'. But the circuit is open at i, hence CR is not energized, but the relay X is energized; hence the calling supervisory lamp Cl is lighted. When the called subscriber takes down his receiver, the relay CR is energized, thereby opening at n the circuit through X, which causes the lamp Cl to go out. The sleeve circuit is now open at n, so that if a busy test is now made at some other section on this called line, the circuits involved in the busy test will be the same as shown in Fig. 2 (*a*).

THREE-WIRE LINE TWO-WIRE CORD SYSTEM

8. In Fig. 3 is shown the three-wire line circuit of a 40-volt common-battery system installed at Paducah, Kentucky, by the American Electric Telephone Company; and in Fig. 4 is shown the two-wire cord circuit. The subscriber's instrument may be used on a two-party selective line by connecting the 1,000-ohm ringer to binding post g, which should be grounded, instead of to binding post a. When the receiver is off the hook, the transmitter and primary winding p of the induction coil are connected in a circuit across the line, while the receiver, the secondary winding s of the induction coil, and the 2-microfarad condenser are connected in a circuit in parallel with the primary winding of the induction coil. The subscriber's instrument seems to be connected the same as those used by the Bell Company, which is fully explained in connection with the Bell central-energy system.

9. The line circuit is the same as that shown in Fig. 1, except that the resistance of the line relay is 300 ohms instead of 500 ohms and the jack-springs are arranged so

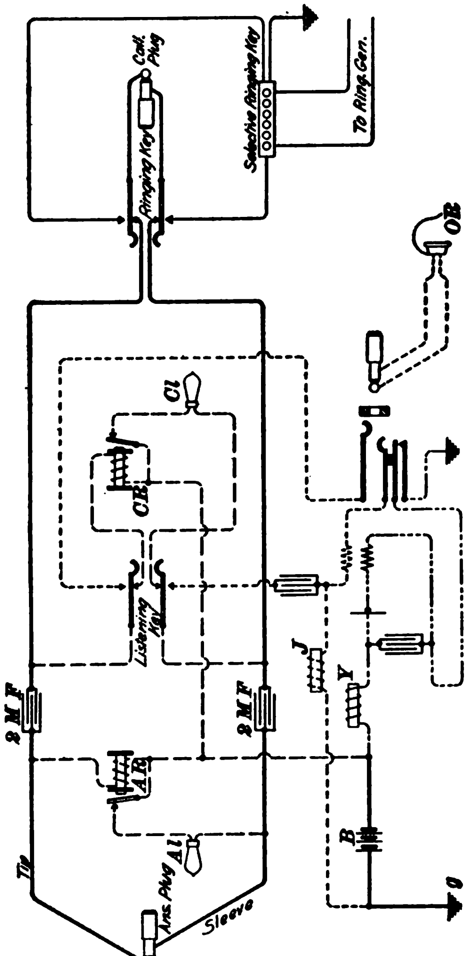


FIG. 4

that the insertion of a plug in any jack connects together the two springs *t*, *r* and thus short-circuits the line relay. Therefore, only two strands are required in the cord circuit, whose operation will be understood after a short explanation.

Inserting the answering plug, Fig. 4, in a jack, Fig. 3, belonging to a line whose receiver has been taken down, allows current to flow from the battery B through the answering supervisory relay $A\,R$–tip of answering plug–tip spring t of jack–f–subscriber's line–o–retardation coil I_1–battery, thus energizing the answering supervisory relay $A\,R$ and preventing the lighting of the answering supervisory lamp $A\,l$. When the receiver is hung up, the supervisory relay releases its armature and the supervisory lamp $A\,l$ is lighted, its circuit being completed through the sleeve of the answering plug, the sleeve s of the jack, and the retardation coil I_1. The subscriber and operator talk to one another through condensers. The busy-test click obtained when a line tested is busy is due to a current that can flow from the battery, Fig. 3, through I_1–r–t–f–o–subscriber's line–sleeve s of jack–tip of calling plug–operator's receiver $O\,R$–secondary winding of induction coil–impedance coil J–battery.

The method used in this cord circuit, whereby the supervisory lamp is at times connected between the sleeve of the cord circuit and the battery, is almost equivalent to putting a dead ground on the sleeve. The four-relay, three-strand, cord circuit shown in Fig. 1 is a much better arrangement.

SERVICE CIRCUITS

10. Switchboard to Chief Operator Circuit.—A brief explanation of the circuits provided for the use of the manager, wire chief, chief operator, and information operator will now be considered merely to give an idea of the arrangement of such circuits in a medium-sized exchange.

Fig. 5 shows a circuit between the main switchboard and chief and information operators. In case it is necessary to connect a subscriber with the chief, or information, operator, the subscriber operator inserts the calling plug of her cord circuit in the jack J. This will cause the lamp L to light because the relay R will be energized by current that flows through the battery B, Fig. 4–supervisory relay $C\,R$–

tip of calling plug–tip spring of jack *J*–relay *R*–impedance coil to ground. On receiving this signal, the chief, or information, operator will insert the plug of her cord circuit in

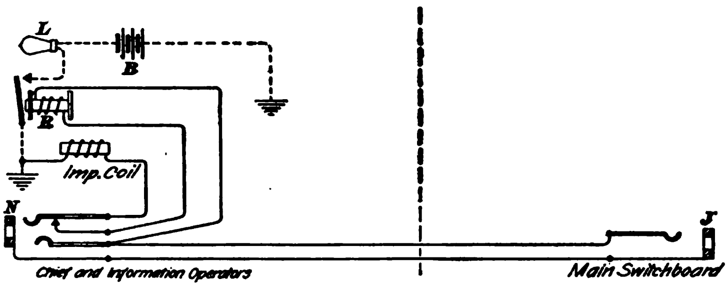


FIG. 5

jack *N*, thereby cutting out the relay *R* and putting the chief, or information, operator in communication with the subscriber.

11. Chief Operator's Cord Circuit.—The chief operator's and information operator's cord circuit is shown in

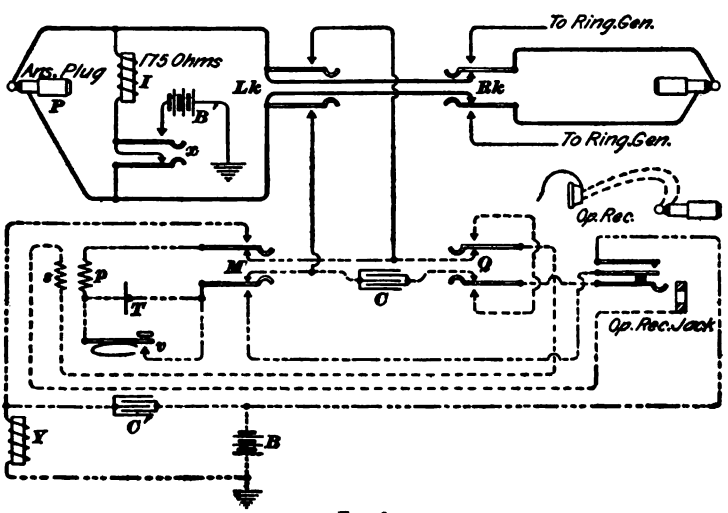


FIG. 6

Fig. 6. The same cord circuit is used for the wire chief, except that the operator's receiver jack is not used, because

the wire chief has a desk telephone. The **holding coil** *I* will hold (the same as a subscriber's telephone when the receiver is off the hook) any line or supervisory signal temporarily connected with a jack in which the plug *P* is inserted. If the listening key *L k* only is closed, the operator's primary and secondary circuits (the latter containing the condenser *C*) are connected in parallel across the cord circuit and then the transmitter receives its current in the same manner as any subscriber's instrument. When the key *M* is closed, current flows from the battery *B* through a local circuit containing the impedance coil *Y*, primary winding *p*, and transmitter *T*; the condenser *C'* is connected as shown to improve the transmission. If the key *Q* is closed, the receiver and secondary winding are in a local closed circuit, as in many central-energy subscribers' instruments.

12. **The wire chief to main switchboard circuit** is shown in Fig. 7. The insertion of a plug in jack *V* cuts

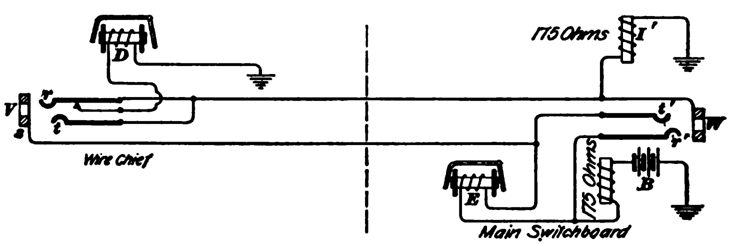


FIG. 7

out the self-restoring drop *D* and operates the self-restoring drop *E*. The insertion of a plug in jack *W* short-circuits the tip and ring springs *t'*, *r'*, hence also the drop *E*, and current flows from the ground *g*, Fig. 4, through battery *B*–supervisory lamp *A l* (the supervisory relay is not yet energized, because the operator's tip conductor circuit is open at the sleeve *s* of jack *V*, Fig. 7)–sleeve conductor–sleeve of jack *W*–spring *r*–drop *D*–ground; thus operating *D*. When the wire chief answers by inserting his plug *P*, Fig. 6, in jack *V*, the circuit is closed from the battery *B*, Fig. 4, through the supervisory relay *A R*–tip side of the operator's cord circuit–spring *t'*, Fig. 7–*s*–*I*, Fig. 6–tip of plug *P*–tip

spring t, Fig. 7–I'–ground, thereby closing the supervisory relay $A\,R$ and disconnecting the battery from the supervisory lamp $A\,l$ and from the sleeve side of the operator's cord circuit.

13. **The chief operator to wire chief circuit** is shown in Fig. 8. If the chief operator closes the key x,

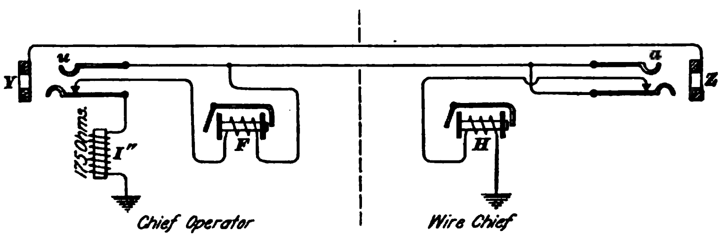


FIG. 8

Fig. 6, which is added for this purpose, and inserts the plug P in jack Y, Fig. 8, current flows from B' through I–tip of plug P–tip spring u, Fig. 8–drop H to ground. The wire chief answers the signal produced by the drop H by inserting a plug similar to P, Fig. 6, in jack Z, thereby cutting out

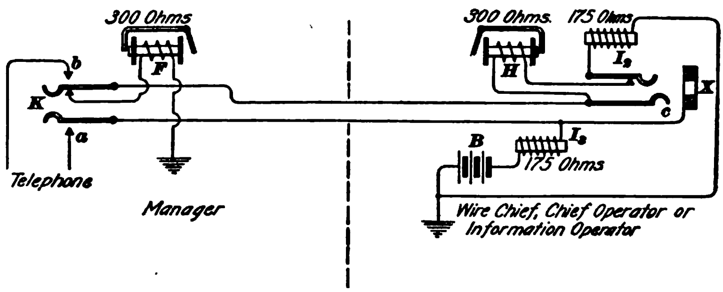


FIG. 9

the drop H. If the wire chief is the first to insert his plug P in jack Z and closes his key x, Fig. 6, current flows from B' through I–tip of plug–tip spring a of jack Z–F–I'' to ground, thereby operating the drop F.

14. **The circuit between the manager and the wire chief, chief operator, or information clerk** is shown in Fig. 9. The manager's telephone is connected through a

key to each circuit. To call up the wire chief, the manager throws the key K associated with the circuit running to the wire chief's desk, thereby allowing current to flow from B through I_3–a–manager's telephone set–b–self-restoring drop H–I_2 to battery, thereby operating the drop H. The wire chief calls up the manager by inserting his plug P, Fig. 6, in jack X, thereby disconnecting drop H and allowing current to flow from B, Fig. 9, through I_3–sleeve of jack X–sleeve of plug P, Fig. 6–coil I–tip side of circuit–c, Fig. 9–drop F–ground; this will operate the self-restoring drop F.

OPERATION OF WIRE CHIEF'S TESTING CIRCUITS

15. The circuits installed for the use of the wire chief, together with the instructions about as issued by the manufacturing company for making the tests with these particular circuits, will now be considered.

The testing cord circuit, shown in Fig. 10, is used in connection with the testing trunk to terminal frame circuit, shown in Fig. 11. The latter, as its name implies, extends from the wire chief's desk to the terminal heads, where it ends in a test clip, or plug, W that can be inserted between the terminals of a line in place of a heat coil. The wire chief is thus able to make all tests for line trouble either through the testing trunk to terminal head, Fig. 11, or through the testing trunk to switchboard, Fig. 12. Whenever the test clip W, Fig. 11, is inserted in the place of a heat coil, calls to or from the switchboard will be carried to the wire chief's desk. In case a call is received in this way during the test, and if the trouble is of such a nature as not to throw the line out of use, the wire chief will establish connection between the line and the switchboard by inserting the plugs of his cord circuit, Fig. 6, in the jacks J, A, Fig. 11. The testing circuit shown in Fig. 10 is also used to enable the wire chief to call and converse over circuits between desks and also to call and converse with an operator or a subscriber over the testing trunk lines to the multiple switchboard.

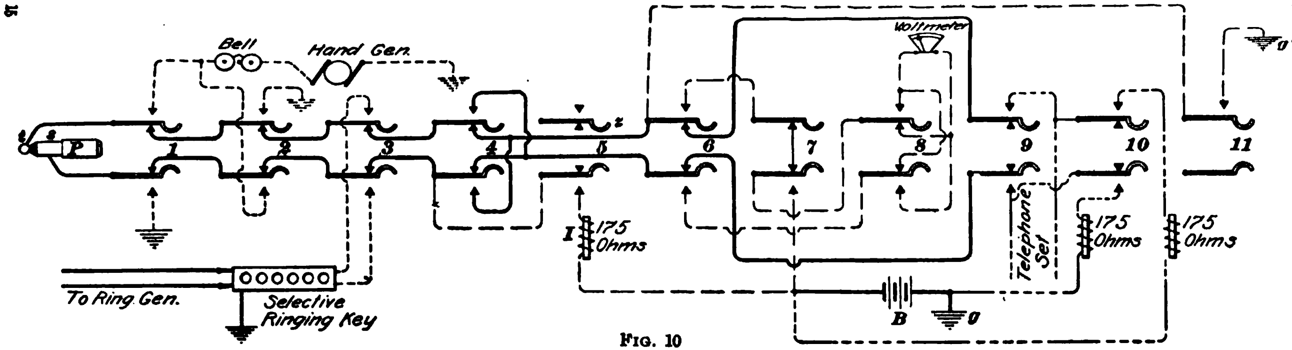


FIG. 10

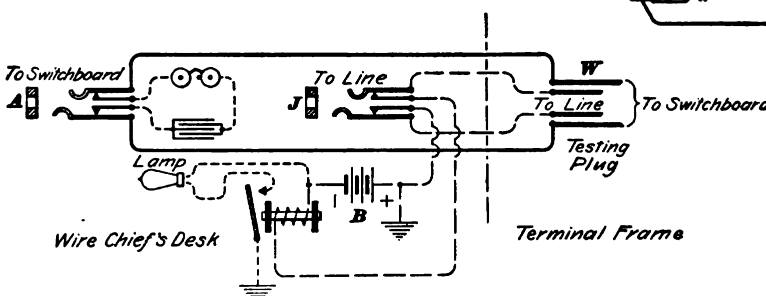


FIG 11

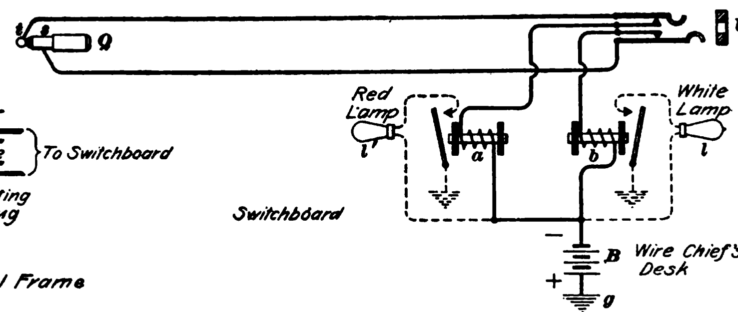


FIG. 12

16. The testing trunk to local switchboard circuit, shown in Fig. 12, is always used in connection with the testing cord circuit. When a line lamp becomes permanently lighted or when a line does not work properly, the operator, or chief operator, will insert a testing-trunk plug *Q* into a multiple jack of the line in trouble and send to the wire chief a memorandum of the trouble. The act of inserting this plug into the line jack will shunt the line relay by relays *a* and *b*, extinguishing the line lamp in case it has been lighted, form a closed circuit through *g*–*B*–*b*–*s*–sleeve of jack at switchboard–retardation coil to ground, thus closing relay *b* and hence lighting the white lamp *l* in the testing-trunk circuit; the wire chief will, as soon as possible, insert the plug *P* of the testing cord circuit, Fig. 10, in the jack *U* of the testing-trunk circuit, Fig. 12, and make the necessary tests, as hereinafter described, for the location of trouble. If, after the plug *Q* has been inserted in the multiple jack and before the wire chief has inserted a plug in jack *U* in order to begin testing, the subscriber takes down his receiver, the red lamp *l′* associated with this testing trunk will light, because a circuit will be closed through *g*–*B*–*a*–*t*–subscriber's line retardation coil to ground, the wire chief will answer and may extend the connection to the switchboard by means of his cord circuit, shown in Fig. 6. If the wire chief is able to determine and clear the trouble immediately he will, by means of an order wire, order the testing trunk plug *Q* removed from the switchboard jack, and the light *l* of the testing-trunk circuit will go out when this has been done.

In case there is a cross or ground on the line and it is necessary to send a lineman to clear the trouble, the testing-trunk plug *Q* should be left in the subscriber's line jack, then the lineman can signal the wire chief by crossing the line with his telephone set.

17. All line tests are supposed to be made with the testing cord circuit, shown in Fig. 10, which provides means for testing any line in the exchange. The keys in this circuit and the use of each is as follows: Ringing keys *1*, *2*, and *3*

enable the wire chief to ring the party whose line is undergoing test; key *1* rings through the tip side to ground; key *2*, through the sleeve to ground; key *3* connects with a master selective key for use with the American Electric Telephone Company's four-party selective ringing system. A reversing key *4* reverses the position of the testing apparatus in relation to the tip and sleeve of the line. A testing key *5* supplies battery to sleeve side of the line for making a test by means of the drop-of-potential method using a voltmeter. A voltmeter key *6* connects a voltmeter across the cord circuit. A battery key *7* connects battery to one terminal of the voltmeter. A voltmeter reversing key *8* reverses the terminals of the voltmeter relatively to the tip and sleeve side of the circuit. A listening key *9* connects the wire chief's telephone set to the testing cord. A battery key *10* furnishes battery through retardation coils for conversation between the wire chief and the subscriber. Key *10* need only be used when the wire chief is making a test from the terminal frame or heads, as the battery will be supplied from the switchboard while making other tests. By means of keys 11 and 4, either side of the line may be grounded.

METHOD OF MAKING TESTS THROUGH SWITCHBOARD

18. Test for Grounds.—To make a test with plug *P*, Fig. 10, inserted in jack *U*, Fig. 12, and *Q* inserted in the multiple jack of the line to be tested, proceed as follows: To test for a ground on the *sleeve side* of the line, throw the battery key *7*, then the testing key *5*, and last the voltmeter key *6*. If the subscriber's receiver is on its hook and the sleeve side of the line is in its normal condition, as shown in Fig. 3, that is, connected through the 175-ohm retardation coil I_1 on the sleeve side of the jack to ground, the circuit will be as shown in Fig. 13, and the drop in voltage around the 175-ohm impedance coil *I* will then be measured by the voltmeter, which should normally show a deflection approximately one-half the battery voltage. If the deflection is greater than half the battery voltage, the sleeve side of the

line is grounded somewhere, as at y. In order to obtain the resistance of a ground on the sleeve side of the line, which has been detected in this way, the voltage of the battery at the time of the test is the only information necessary in addition to the reading just taken. Suppose that at this time the battery voltage is 40 and the voltmeter shows a deflection of 30; this means that the resistance of the retardation coil I in the cord circuit is practically $\frac{30}{40}$ of the entire resistance of the circuit from the non-grounded side of the battery through this impedance coil I and then in parallel through the impedance coil I_1 and the ground at y to the

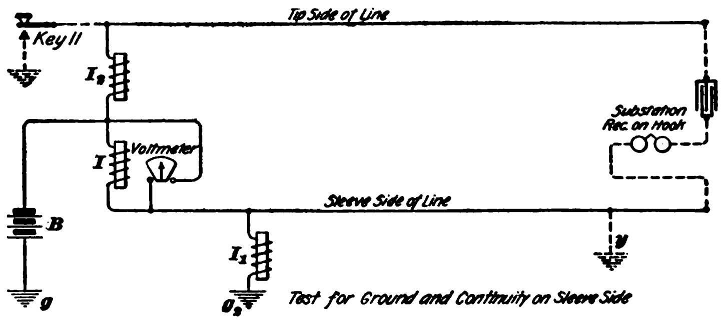


FIG. 13

earth. Thus, as the resistance of the impedance coil I is 175 ohms, the joint resistance of the grounded line and the 175-ohm impedance coil I_1 on the sleeve side of the jack is $x = \frac{175 \times y}{175 + y}$. But 175 must be $\frac{30}{40}$ of $175 + x$ or $\frac{30}{40}(175 + x) = 175$, or $x = 58$; the resistance of the line to ground must be $y = \frac{175 \times x}{175 - x} = \frac{58 \times 175}{175 - 58} = 86$ ohms. This, of course, represents the resistance of the sleeve side of the line from the exchange to earth with the subscriber's receiver on its hook.

19. To test for ground on the *tip side* of the line, throw the reversing key *4*, voltmeter key *6*, and battery key *7*, which will give the connections shown in Fig. 14. If the tip side is grounded at z, the voltmeter will be deflected; but if

the subscriber's receiver rests on the hook and there is no deflection, the tip side of the line is clear. If the subscriber's receiver is off the hook and the deflection is greater than usual on a good line, either one or both sides of the line may be grounded. In case of a deflection, the resistance of the tip side of the line can be obtained by the same method as for the sleeve side, except that, if the subscriber's receiver is on the hook, there will be no parallel resistances to contend with. Thus, if the voltmeter shows a deflection of 30,

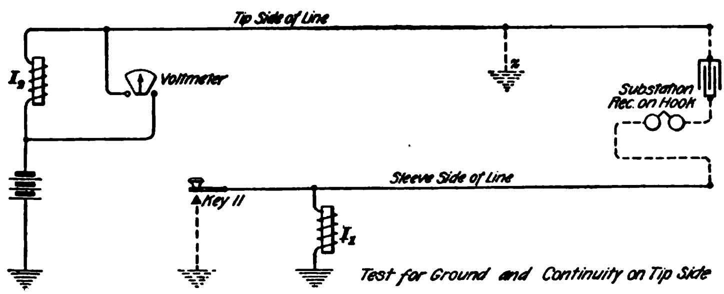


Fig. 14

this means that the resistance of the impedance coil I_2 in the tip side of the line is practically $\frac{30}{40}$ of entire resistance of the circuit from the non-grounded side of the battery through this impedance coil I_2 and the line to ground. Since the resistance of the impedance coil is 175 ohms, which is $\frac{30}{40}$ of the total resistance, then the total resistance is $\frac{40}{30} \times 175$ ohms and the resistance of the line to ground, which is $\frac{10}{40}$ of the total resistance, must be $\frac{10}{40} \times \frac{40}{30} \times 175 = \frac{1}{3} \times 175 = 58$ ohms.

20. Test for Continuity of Circuits.—First, test the sleeve of the line for ground (closing keys *7*, *5*, and *6*, Fig. 10) as already described; if it is free from grounds, the deflection of the voltmeter should be about equal to one-half the voltage of the battery. If the subscriber's receiver is off the hook, the deflection will be increased, varying with the resistances of the different lines. Then close the grounding key *11*, keys *7*, *5*, and *6*, Fig. 10, being left closed, which will give the circuit shown in Fig. 13 with key *11* closed. If the line is continuous and the receiver off the hook, the

deflection of the voltmeter should be increased because the resistance through the line circuit and key *11* to ground is less than before, hence the current and fall of potential through *I* is greater.

To test the tip side of line for continuity, close keys *7*, *6*, and *4*, which gives the circuit shown in Fig. 14; if the line is clear, there will be no deflection; if the receiver is off its hook, the voltmeter will be deflected varying with the resistances of the different lines. Closing the grounding key *11* should increase the deflection of the voltmeter because it short-circuits the 175-ohm impedance coil I_1 in the sleeve side of the line circuit.

21. Test for Crosses.—In order to determine whether there is a cross between two lines, ground one of them at the main frame and test the other for ground. For instance, if the sleeve side of one line is grounded and it is crossed with the sleeve side of any other line, which is being tested, as shown in Fig. 13, the voltmeter is practically connected across the battery and will therefore indicate almost the full voltage of the battery, depending somewhat on the resistance at the cross.

22. Test for Short Circuit.—The resistance of each line should be carefully measured with the receiver off the hook, at the time the line is in good condition; the resistance of each line should be recorded and any decided variation from that resistance will be an indication of trouble.

23. Test for Foreign Currents.—With plug *P*, Fig. 10, in jack *U*, Fig. 12, and plug *Q* in a jack at the switchboard, press the voltmeter key *6*. The voltmeter will then be connected across the line, a 175-ohm impedance coil between the sleeve side and ground, and a 175-ohm impedance coil from the tip side through battery to ground. Observe the deflection due to current from the office battery through the voltmeter and both impedance coils, then press the grounding key *11*; if there is no foreign current in the sleeve side of the line, the voltmeter deflection should be about zero, because one terminal is directly grounded and

the other is grounded through the impedance coil on the sleeve side of the circuit; if there is a cross with a live wire, the deflection produced will depend on the voltage of the foreign current. Restore the grounding key, throw the reversing key *4*, note the deflection, and again press the grounding key; the reading on the voltmeter should then indicate whether there is a foreign current on the tip side of the line, due allowance having been made for the voltage of the office battery through the 175-ohm impedance coil on the tip side of the jack.

METHOD OF MAKING TESTS THROUGH TERMINAL FRAME

24. Test for Grounds.—Although it is easier to make all the tests described above through the switchboard, they can also be made from the terminal heads by inserting the testing clip *W*, Fig. 11, in place of a heat coil at the terminals of the line to be tested and the plug *P*, Fig. 10, of the testing cord circuit in the line jack *J*, Fig. 11, as follows: To test for a ground, throw the battery key *7*, voltmeter key *6*, and testing key *5*. If the sleeve side is grounded, the voltmeter needle will be deflected and the resistance to ground can be obtained by the same method used for obtaining the resistance to ground on the tip side when the test was made through the switchboard.

25. The insulation resistance of both sides of the line with the subscriber's receiver off the hook can be obtained as follows: Throw voltmeter key *6* and battery key *7*, which puts the voltmeter in series with the battery and the sleeve side of the line.

If r = resistance of voltmeter;
d = voltage of battery, which is obtained by also closing key *11*;
d' = deflection of voltmeter when keys *6* and *7* only are closed;
R = insulation resistance of whole line to ground.

$$R = r\left(\frac{d}{d'} - 1\right)$$

This formula was derived and fully explained in *Electrical Measurements*.

26. Test for Continuity of Circuits.—With a subscriber's receiver off its hook, throw the voltmeter key *6* and battery key *7*, and then press the grounding key *11*; a deflection of the voltmeter will indicate a continuous line.

27. Test for Crosses.—Ground one line at the terminal head and test the other for a ground.

28. Test for Short Circuits.—Measure the resistance of the line when the receiver is off the hook; if this does not agree with the resistance of the line taken with similar connections at the time when the line was in good condition, the chances are that the line is short-circuited; at any rate, such a condition indicates trouble.

29. Test for Foreign Currents.—Throw the voltmeter key *6* and then press the grounding key *11*. If there is a foreign current from a grounded source of supply to the sleeve of the line, the voltmeter should show its voltage. Release the grounding key, throw the reversing key *4*, and then again press the grounding key *11*; if there is a foreign current on the tip side of the line, the reading of the voltmeter will indicate its voltage.

EUREKA ELECTRIC COMPANY'S CENTRAL-ENERGY SYSTEM

THREE-WIRE LINE, TWO-WIRE CORD, NON-MULTIPLE SWITCHBOARD CIRCUIT

30. The circuit used for medium- and small-sized non-multiple central-energy switchboards by the Eureka Electric Company is shown in Fig. 15. It is a three-wire line, two-wire cord circuit. The subscribers' telephone circuit is explained in connection with the Bell central-energy system.

31. Operation.—When the subscriber *A* removes his receiver from the hook, current flows through *B*–impedance

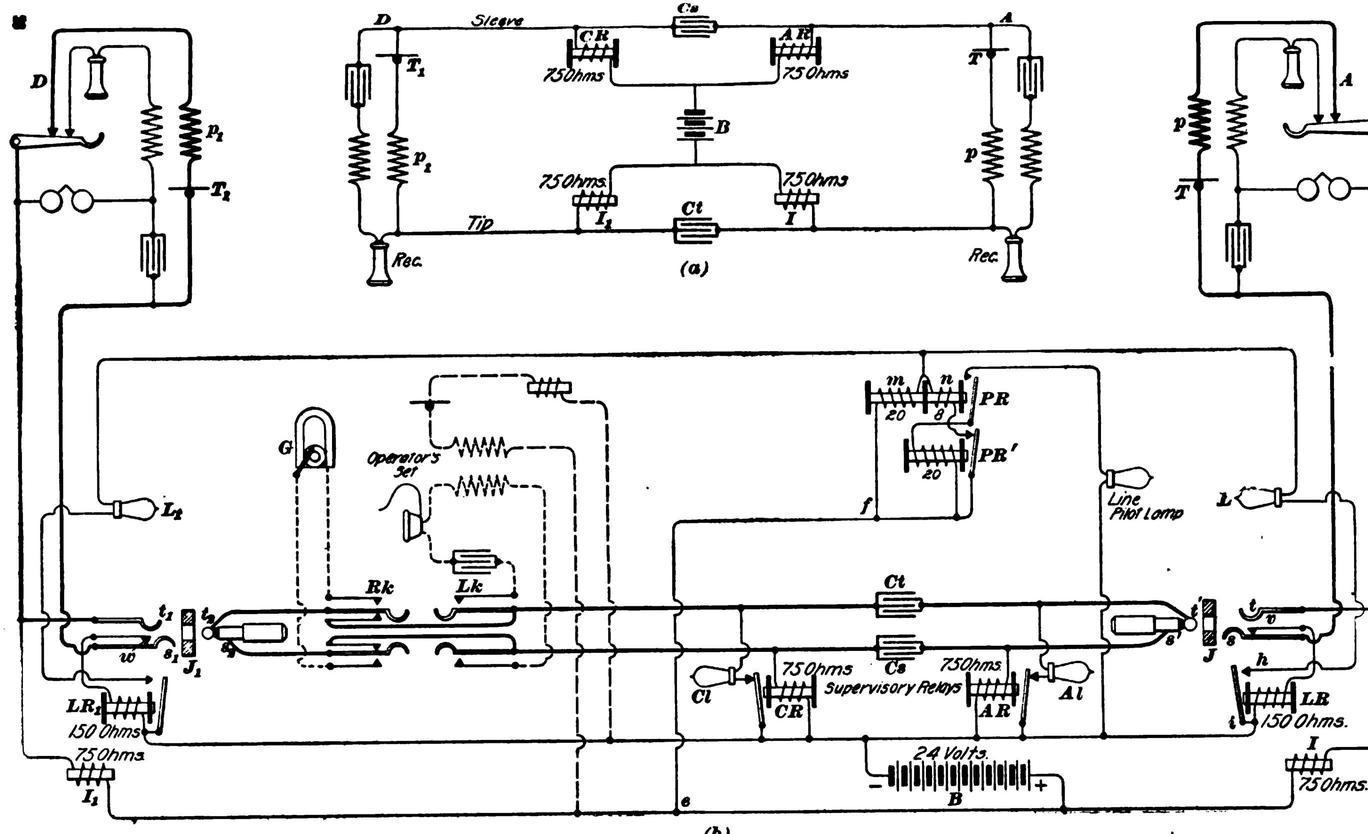

D
Sleeve
Cs
A
CR
AR
750hms
75 Ohms
T1
T
B
P1
p
750hms
75 Ohms
Ct
Tip
I1
I
Rec.
Rec.
(a)
D
P1
T2
A
p
T
G
Operator's Set
Rk
Lk
m
n
20
8
PR
PR'
f
Line Pilot Lamp
L
L2
Ct
Cs
t1
t2
s1
s2
w
J1
t'
s'
J
t
v
s
h
LR
150 Ohms.
LR1
150 Ohms
750hms
I1
Cl
CR
750hms
Supervisory Relays
750hms.
AR
Al
24 Volts.
B
e
I
75 Ohms.
(b)

FIG. 15

coil *I*–winding *p* of the subscriber's induction coil–transmitter *T*–*s*–*v*–line relay *L R*, thus operating the latter, and allowing current to flow through *B*–*e*–*f*–winding *m* (20 ohms) of the pilot relay *P R*–line lamp *L*–*h*–*i*. The current flowing in this circuit is sufficient to close the relay *P R*, but not sufficient, on account of the 20 ohms in the winding *m*, to fully light the line lamp *L*. However, the closing of the relay *P R* allows current to flow through the 20-ohm relay *P R'*–armature of *P R*–line-pilot lamp, thereby lighting the line-pilot lamp and closing relay *P R'*. Sufficient current can now flow through the armature of *P R'*, 8-ohm winding of *P R*, and line lamp *L* to light it to full brilliancy and the currents through windings *m* and *n* assist each other in holding the relay *P R* closed.

The operator now inserts the answering plug in the jack *J*, thereby opening at *v* the circuit containing the line relay *L R*, which releases its armature, thus cutting off current from the line lamp *L* and pilot relay *P R*, causing the latter to release its armature, which in turn causes *P R'* to release its armature. Current can now flow through *B*–impedance coil *I*–line and subscriber's instrument–*s*–*s'*–supervisory relay *A R*, thereby closing the latter, which attracts its armature and prevents current from flowing through the answering supervisory lamp *A l*.

32. In order to obtain the number of the subscriber desired by *A*, the operator closes her listening key *L k*, which bridges her receiver through a condenser and the secondary winding of her induction coil across the cord circuit, in each side of which is a condenser *C t* and *C s*, respectively. The operator then inserts the calling plug in the proper jack *J*, and closes her ringing key *R k*. The line relay being on open circuit at *w*, is not energized and the ringing current from the generator *G*, which is bridged across the calling cord circuit, flows through the line and bell at station *D*. The closing of the ringing key opens the circuit toward the answering side of the cord circuit, so that no ringing current can pass through the answering side to the calling

subscriber's telephone. When the ringing key is released, current flows through B–I_1–t_1–t_2–Cl, thus lighting the calling supervisory lamp Cl until subscriber D takes down his receiver. Then current flows through B–I_1–subscriber's line–primary coil p_1–transmitter T_1–s_1–s_2–CR. This current causes the calling supervisory relay CR to attract its armature, thus putting out the calling supervisory lamp Cl.

As the subscribers hang up their receivers, the corresponding supervisory lamps will light. For instance, when the receiver at station A is hung up, the condenser and bell are connected in series across the line wire, hence no battery current can flow through B–I–line and subscriber's station–s–s'–AR, consequently AR releases its armature, thereby allowing current to flow through B–I–t–t'–Al. The answering supervisory lamp Al is, therefore, lighted.

33. The two subscribers' talking circuits are connected together through the condensers Ct and Cs. Each subscriber's transmitter receives current through a separate pair of coils consisting of one impedance coil and one supervisory relay. Since the impedance coil and supervisory relay are equal in resistance, and probably also in inductance, the circuits are well balanced and the arrangement during transmission, as shown in Fig. 15 (a), is such as to be capable of giving good transmission. There appears to be no unnecessary relays or coils, except perhaps in the arrangement of the pilot relays, which seem unnecessarily complicated; however, only one set of pilot relays is required for each operator's position.

A low-voltage cord-circuit lamp must be used in order to work through the 75-ohm coil I. This lamp, in all probability, is designed for 10 or 12 volts pressure. The line lamps work direct on 24 volts, thereby requiring lamps of two voltages for the exchange. This is always considered a disadvantage, as the lamps are liable to become mixed and get into the wrong circuit and cause trouble.

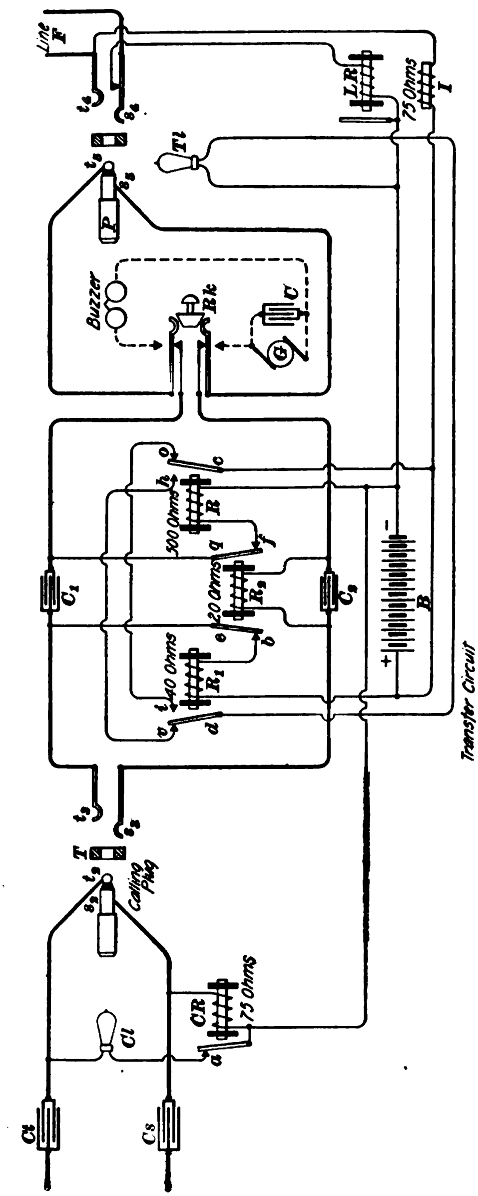

Line F
LR
75 Ohms
I
Tl
P
Buzzer
Rk
G
C
C_1
C_2
500 Ohms
20 Ohms
40 Ohms
R
R_1
R_2
B
Transfer Circuit
T
Calling Plug
CR
75 Ohms
Cl
Ct
Cs

FIG. 16

COMMON-BATTERY TRUNK CIRCUIT

34. The common-battery trunk, or transfer, circuit used by the Eureka Electric Company in connection with their central-energy system is shown in Fig. 16. The battery B in this figure is the same battery as B in Fig. 15. The relay contacts in Fig. 16 are shown in their normal positions. The operator at one section of this transfer, or express, switchboard, who receives a call for a subscriber whose line signal and jack are located at another section, communicates with the operator at the latter section through an ordinary order-wire circuit, telling the second operator the number desired and in return is informed what transfer trunk to use. The first operator then inserts the calling plug of one of her cord circuits in the trunk jack designated by the second operator, say jack T. Current then flows through B–R_1–b–e–t_3–t_2–Cl–a–B, thus lighting the supervisory lamp Cl and energizing the relay R_1, thereby allowing current to flow through B–c–o–i–d–Tl–B, and light the trunk lamp Tl, which is located near the trunk plug P. The second operator then inserts the trunk plug P in the jack of the subscriber wanted. Current now flows through B–impedance coil I–t_4–t_5–q–f–R, causing the armature of R to rest against h, thus opening at o the circuit through the trunk lamp Tl, which, therefore, goes out.

35. Use of Condenser Around Pole Changer.—The operator closes the ringing key Rk, thereby ringing the desired subscriber's bell. If the generator G is a pole changer, a condenser is usually connected, as shown, around the pole changer. The use of a condenser around the contacts of a pole changer is primarily to prevent sparking of the contacts when delivering a large current. This condenser is of such small capacity that it only assists the action to a very slight extent. If a large condenser were bridged across the pole changer it would result in a continuous load even when not ringing a subscriber's line. This would, of course, waste energy.

36. When the desired subscriber takes down his receiver, current flows through B–I–subscriber's line F, and telephone instrument–s_4–s_6–R_2–s_3–s_2–CR, causing both R_2 and CR to attract their armatures, thus putting out the supervisory lamp Cl and cutting out relays R and R_1, thereby causing c to rest against o and d against v and therefore still leaving the trunk lamp Tl on open circuit at h.

Line F is supplied with current for its transmitter through the impedance coil I and supervisory relay CR. The two subscribers' talking circuits are connected together through a circuit containing only one coil R_2 which is, moreover, shunted by a condenser C_2. In each side of the circuit, there are two condensers in series, but such an arrangement does not interfere with good transmission.

37. The entire supervision is with the originating operator and she receives the clearing signals from both subscribers. For when the receiver on line F is hung up, the supervisory relay CR no longer receives sufficient current to hold its armature, therefore the supervisory lamp Cl lights.

The relay R_2 is also deprived of current when the subscriber on line F hangs up his receiver, thus allowing its armatures e and q to make contact with b and f, respectively. Two circuits are thus established, one through B–relay R_1–b–e–t_3–t_2 lamp Cl–armature a, and the other through B–I–t_4–t_6–q–f–R. The two relays R_1 and R are thus energized and as their armatures each make contact with a circuit that is open, no signal is displayed. However, when the operator notices the disconnect lamp Cl lighted, she pulls down the plug from the trunk jack T, thereby opening the circuit of relay R_1 and allowing its armature to fall back. A circuit is now established through B–c–h–v–d–Tl. The disconnect lamp Tl is lighted and the trunk operator pulls down the plug P from the line jack. This act deprives relay R of current, the falling back of its armature opens the circuit of lamp Tl, thus restoring everything to its normal condition with no current flowing in any part of the circuit.

MAIN AND BRANCH EXCHANGES

MAIN EXCHANGES

38. In large cities, where the number of subscribers is too large for one multiple switchboard, either a divided multiple switchboard or a number of separate switchboards must be used. The divided multiple switchboard never met with much favor and seems to be going out of use in the United States. If several multiple switchboards are used, trunks circuits must be used between them, hence it makes practically no difference in the arrangement and operation of the circuits whether the several switchboards are all in one building or in different parts of the city. If each switchboard is located in about the center of the district it serves, the average length of the subscribers' lines is so much shorter than would be the case if all lines ran to one main, centrally located exchange building, that it pays well in large cities to maintain quite a number of separate exchanges in place of one very large exchange.

LOCATION OF EXCHANGES

39. The selection of a location for a central office or exchange is very important. For each group of subscribers, there is a point called the *center of distribution*, from which the average length of subscribers' lines is a minimum. When the exchange is located at that point, the cost of construction and maintenance will usually be a minimum. In some cases, however, the saving to be derived on account of locating the office at the center of distribution is more than offset by the greater cost of real estate or rent; in which case it is often advisable to locate the office at a point removed from the center of distribution at which the annual saving on investment in real estate or rent will more than compensate for the increased first cost of outside construction.

40. To find the center of distribution for a given group of subscribers, locate them on a map of the city or town. First draw a horizontal line so that there will be as many subscribers above as below it, then draw a vertical line so that there will be as many subscribers on the right side as on the left side of it; the intersection of these two lines is the center of distribution. In locating the center of distribution, due consideration must be given to the probable future growth, as an unequal growth in one direction will tend to carry the center of distribution in that direction.

Where there are to be several exchanges, the total number of subscribers should be divided into the desired number of approximately equal groups, an exchange being located at the center of distribution of each group. Where the number of lines does not exceed 6,000, it is practical to use one multiple switchboard, provided it is not more economical, on account of the long length of many of the line wires thus required, to use two or more smaller exchanges.

41. In large cities, a very large percentage of the calls received in any one office are for connection with subscribers whose lines terminate at other offices. The Chicago Telephone Company has found, for instance, that 80 to 90 per cent. of all the calls originating at one office are for subscribers whose lines terminate in other offices. There seems to be a tendency toward the location of multiple jacks in front of the trunk operators only, and to trunk to these operators all calls, whether they originate within the office or at another office, instead of providing complete multiple equipments before the operators at each section of the switchboard.

42. Pilot Lamps.—It has been customary to install one **pilot lamp** for each operator's position, to locate it high up in the middle panel, and to have it operate in connection with any line lamp burning at that position. A monitor sitting at a desk in front of the switchboard could see the pilot lamps. If one remained lighted an undue length of time she would make an investigation and determine whether or not the operator had too many calls to answer, or for any other

reason was neglecting to answer calls as rapidly as she should. The operator, whose eyes were usually attracted only to the lower part of the switchboard, could not very readily observe the pilot lamps and hence had to rely on her observation of the line lamps entirely in order to determine when a call was received. Thus the pilot lamp served merely as a check on her work.

Some companies are now placing one pilot lamp in each panel and below the answering jacks. This arrangement is used where each monitor walks up and down behind a definite number of operators assigned to her care. The monitors can now readily see a pilot lamp although placed low down on the board and furthermore one brilliant lamp in each panel where the operator can easily see it, readily attracts her attention, not only to the fact that some line lamp has lighted, but also directs her to the panel where that line lamp is located. If an operator, for instance, is calling a subscriber whose multiple jack is at the extreme left of the section, she might not instantly observe a lamp light at the extreme right of her answering jack panel; but the greater brilliancy of the pilot lamp will cause her to turn more quickly to this call and she can be prepared to answer it while completing the connection to the other subscriber.

Furthermore, if a monitor observes a pilot lamp burning in a panel that may be readily reached by either of two operators, she can at once determine which operator should answer the call, without waiting to locate the particular line lamp. This facilitates the distribution of calls among the operators during very busy times.

PRIVATE-BRANCH EXCHANGES

43. The **private-branch exchange** is one adapted to give service between subscribers located in some institution such as a factory, large office building, or hotel, and also between these subscribers and any other subscribers in the town or city connected with the main exchange. It is called a **private exchange** because it is under the control of the

owner of the institution or building that it serves, and it is called a branch exchange because it operates in conjunction with, and forms a part of, a larger exchange system. Private-branch exchanges usually consist of a one- or two-position switchboard with a capacity of 100 or 200 lines, respectively, and are generally operated on the central-energy system. In many cases, the current is supplied from the main exchange through as many pairs of wires as may be necessary to carry the battery current required. The ringing current may also be supplied over a pair of wires from the main exchange. In some cases, it is cheaper to use a pole changer or even a ringing motor-generator operated from the storage-battery leads. One or more circuits, called *trunk lines*, connected with the main exchange are also provided.

Connections between the private-branch-exchange subscribers are made in the usual manner by a private-branch-exchange operator. Connections between the subscribers of the branch exchange and the subscribers of the main exchange are made in the same way as between two subscribers in different offices of a city exchange, that is, through trunk lines joining the two switchboards. It is quite customary to use one-way trunks between the private-branch exchange and the main office, that is, all connections from the main office toward the private-branch exchange are made through one set of trunks, while connections from the private-branch exchange toward the main exchanges are made through the other set of trunks. It is desirable that the work of the main-exchange operator should not be made more difficult and complicated by having her ends of the private-branch-exchange trunks operate in a manner different from her other trunk and line circuits, the extra work should preferably be given to the private-branch-exchange operator, because the latter usually has enough time not only to make the necessary connections, but also to do much of the work of obtaining connections, which would, otherwise, have to be done by the subscribers whose lines terminate at the private-branch exchange.

44. The private-branch exchange saves running all the subscribers' line wires all the way to the main exchange, a few trunk lines usually being sufficient to care for all the through traffic. In large cities, especially where underground cables must be used, the use of private-branch exchanges reduces both the first cost of construction and maintenance. However, private-branch exchanges are usually small, and therefore cost more per line than main exchanges; moreover, their maintenance is very important, especially when they serve very busy subscribers whose time should not be wasted. Since the operators of private-branch exchanges are not in the employ of the operating company, the latter has no direct control over them, and therefore the private-branch switchboard may not receive the best of care and attention. The private-branch exchange should, therefore, be constructed so that its first cost will not be excessive, and it should operate in a simple manner, even though the speed of operation is thereby sacrificed.

PRIVATE-BRANCH SWITCHBOARDS

45. There are three ways in which supervisory signals may be operated when a subscriber connected with a main exchange calls for a subscriber connected with a private-branch exchange. There is considerable difference of opinion as to which method is the most desirable. In order to avoid mistakes and to economize the time of the main-exchange operator, all her circuits should be arranged to work in a similar and regular manner. In the Electrical World and Engineer, K. B. Miller and C. S. Winston give the following explanations of the three methods that have been used commercially for enabling the branch-exchange subscriber to clear out or resignal the office:

46. "The first of these methods is to place in the control of the private-branch subscriber during a connection, the regular cord-circuit supervisory signal at the main office only, so that this lamp will light at the main office when the

subscriber hangs up his receiver, in exactly the same manner as if he were on a regular subscriber's line entering the main office direct. On both subscribers hanging up their receivers, the main-office operator would pull down the connection, and in doing so the removal of the plug from the private-branch-exchange trunk jack would light the disconnect lamp at the private-branch exchange, after which the private-branch operator would pull down the connection.

"From the standpoint of clean operating at the main board, this scheme is perhaps best of all. It is found, however, that this arrangement is not desirable from the standpoint of the private-branch subscriber, and also has its disadvantages in regard to the city subscribers who desire connection through the private-branch exchange. As illustrative of this point, it may be said that a main-office subscriber will often call up a certain member of a business firm through its private-branch exchange; on stating his business this person, so called, will at once recognize that the business may be transacted in another department, whereupon, instead of being able to signal the branch-exchange operator direct by moving his hook up and down, he is obliged to tell the person who desires to transact the business to call up another line in the private-branch exchange. This necessitates the calling party beginning all over again at the main office, and securing the connection perhaps over another trunk line.

47. "This fault is elimated in the second of the three methods, in which the private-branch-exchange subscriber has within his control during a connection, a lamp at the private-branch board only, the action of his hook causing no effect whatever at the main office. Under this condition, a disconnection is effected when both subscribers hang up, by the private-branch-exchange operator first pulling down the trunk connection in response to the lighting of the lamp under control of the private-branch subscriber, thus lighting the supervisory lamp at the main office. The main-office subscriber having also hung up, the subscriber operator at

the main office sees both lamps lighted and pulls down the connection. It will be seen that the operation at the main office is thus rendered in nowise special, the subscriber operator receiving both supervisory signals in exactly the same manner as if two local lines had been connected, the only difference being that instead of both supervisory lamps being operated directly by the movement of the subscriber's hooks, one of them is operated by the action of the private-branch-exchange operator in pulling down the connection.

"With this arrangement, a private-branch-exchange subscriber who has been called and who desires the calling party put in connection with another person in the private-branch exchange, has only to move his hook up and down to signal his own private-branch operator, whereupon she will complete the connection with the calling subscriber and whatever other private-branch-exchange line is designated. Another advantage of this second method of arranging the supervisory signals is that if the branch-exchange subscriber desires to signal for another connection, after the close of a conversation, he can at once secure the attention of the private-branch operator and have her attend to it for him, hanging up his own receiver until she secures the party wanted. This system has the disadvantage of requiring a somewhat more complex cord and trunk circuit at the private-branch exchange.

48. "In the third method, used to a large extent by both Bell and independent companies, the private-branch subscriber has within his control the supervisory signal at *both* the private-branch exchange and the main office, thus when he hangs up his receiver both lamps light, thus sending in a disconnect signal directly to the main office and to the private-branch office simultaneously. Under this arrangement, some confusion is liable to occur by both operators coming in on a circuit at the same time in response, for instance, to the private-branch subscriber's action of moving his hook up and down. In doing so, he usually desires the attention of the private-branch operator, rather than of the

main-office operator, and the main-office operator may notice this at once and cut her telephone out of the circuit. If the private-branch subscriber desires to have the party with whom he is connected, connected with another line in the private-branch exchange, the main-office operator is not likely to pull down the connection in response to the movement of his hook, because the main-office subscriber will not have hung up his receiver, as he will be waiting for the new connection.

"This method of having the signals at both the main office and the private-branch office under the control of the private-branch subscriber, has an advantage in point of simplicity and first cost, as the circuits are very simple, and it has a further advantage in that it tends to clear the main-office cord circuits quicker after a connection than in the second method described.

49. "All things considered, from an operating standpoint only, it is probable that the second method, where the private-branch subscriber controls a supervisory lamp at the branch exchange only, is best. It is not, however, quite as simple as the third method, and therefore the item of first cost and maintenance enters as an offset.

"There appears to be no definite standard for the operation of private-branch-exchange systems established by the various Bell companies, as, apparently, the different operating companies have their own ideas, which the manufacturing company follows. There seems, however, to be a tendency among the Bell companies to adopt the method of operation in which the private-branch subscriber's supervisory signal goes to the private-branch operator alone, the disconnect signal at the main office being given when the private-branch operator pulls down the connection. However, the system which appeared in 1904 to be the standard for the Chicago Telephone Company employed the third method, having the supervisory signals of the private-branch subscriber go simultaneously to the main office and to the private-branch exchange.

50. "In most of the Kellogg systems, notably those of the Home Telephone Company, of Los Angeles, California, the third method of conveying the clearing-out signals is used, where both the main-office and the private-branch operators receive the private-branch-exchange subscriber's clearing-out signal simultaneously. In these systems, the trunk line ends in a plug and a drop, the operator connecting a trunk to any private-branch line by inserting the plug of the trunk into the jack of the private-branch line. The trunk line is, in this case, provided at the private-branch end with a supervisory signal in the form of a lamp, this lamp, together with the supervisory lamp of the cord used at the central office in connecting with the other end of the trunk line, being under the control of the private-branch subscriber during a connection. This plan of terminating the private-branch end of the trunk lines in plugs is also said to be largely used by the various Bell companies. It, of course, necessitates a change of cords by the private-branch operator when a trunk connection is to be made, as she usually answers a local call by inserting one of the plugs of a pair of local cords into the jack line."

SOURCE OF CURRENT FOR PRIVATE-BRANCH EXCHANGES

51. The method of supplying current for talking and signaling purposes to private-branch switchboards has been the subject of much thought, and the usual practice is, unless the private-branch board is very close to the central office, to install a separate storage battery at the private-branch exchange and to charge this over the trunk lines when not in use. If the battery is to be used while being charged, a 10- to 20-microfarad condenser is frequently connected across the charging leads at the branch exchange to reduce the hum caused by the charging generator located at the main exchange. In fact, a battery is not necessary at the branch exchange if a 20-microfarad condenser is connected across one or more pair of line wires used as battery leads from the main exchange.

In the system of the Chicago Telephone Company, the battery located at the private-branch exchange is normally connected to the cord circuits on the private-branch board through retardation coils in the usual manner, so as to serve when two private-branch subscribers are talking together. If, however, a private-branch subscriber is connected through a trunk to the main office, he draws his talking current directly from the main-office battery over the trunk lines, a locking key being provided for each circuit by which the operator may cut off the private-branch battery from the pair of cords when so used.

52. In some of the private-branch-exchange systems installed by the Kellogg Company, the private-branch operator is provided with the regular pairs of cords and plugs for making all connections, each cord and plug being provided with a supervisory signal the same as in larger central-energy exchanges. The trunk line terminates on a private-branch board in a jack and an ordinary ring-down drop, this drop being manually restored by the operator in response to a ring from the central office; otherwise the operation of the system is the same as that of the Chicago Telephone Company, except that the act of cutting off the battery from any cord circuit is accomplished automatically rather than manually. The battery is normally connected with each pair of cords and plugs; but as soon as the operator inserts the plug in the trunk jack, a relay is operated that cuts off the battery from the cord connected with the trunk jack, thus allowing the signal connected with that cord to be operated by current from the main office.

PARTY LINES ASSOCIATED WITH PRIVATE-BRANCH EXCHANGES

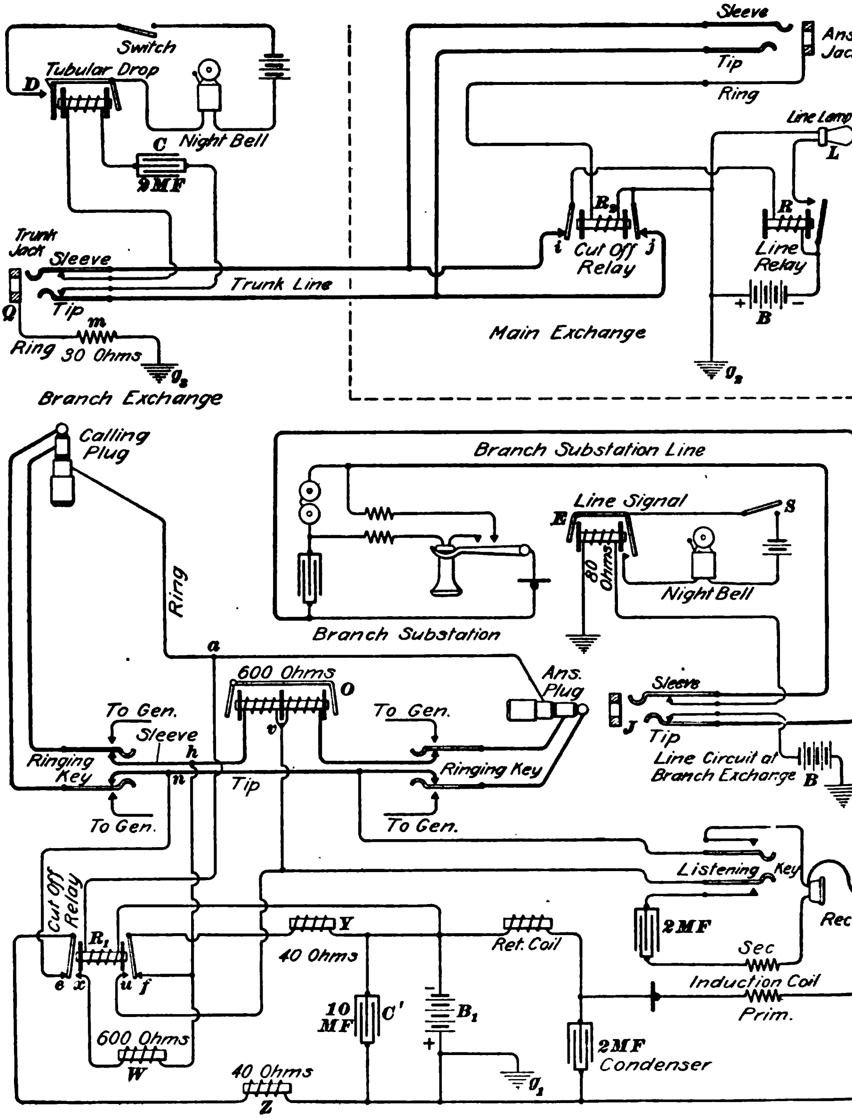
53. Sometimes in private-branch-exchange work, it becomes desirable to use party lines and to afford means whereby the different parties on a line may call each other without calling the branch office, or may call the branch office without calling the other stations on the line. This is often

desirable in large institutions extending over considerable territory. It affords the advantages of a private line between various departments in combination with that of city service. In giving such service as this in connection with the modern exchange system, it is customary, while supplying all current for talking purposes from a common battery, to resort to magneto-calling between the stations of a line. Thus each station is provided with the usual central-energy talking and call-receiving apparatus, and with a magneto-generator adapted to be bridged across the line when operated. In order to prevent the line signal at the private-branch exchange being operated by the current from the magneto-generator, a differentially wound line relay is used, having one winding in each limb of the line. Any current sent over the metallic circuit of a line will therefore not operate this signal, and thus any subscriber on the line is enabled to call any other, the same as on any bridging-bell party line, without calling the exchange. In order to enable any subscriber to call the central office, a push-button key is provided, which grounds the live, battery, or non-grounded side of the line, as it is variously termed, thus causing the operation of the line relay and lighting the line signal.

PRIVATE-BRANCH CENTRAL-ENERGY EXCHANGE NO. 1

54. In Fig. 17 is shown the line, cord, and trunking circuits of a central-energy private-branch exchange in which the supervisory signal at the branch exchange is always under the control of the calling branch-exchange subscriber. The line signal *E* in the branch-exchange line circuit consists of an 80-ohm magnetic signal that restores itself by gravity, a night-bell circuit being provided. As the switchboard is not a multiple switchboard, no busy test or connections with the sleeves of the jacks associated with the branch substations are required. *W*, *Y*, and *Z* are retardation coils.

55. Operation.—The removal of the branch subscriber's receiver from the hook operates the line signal *E* and also rings the night bell, if the switch *S* is closed. The



Switch
Tubular Drop
D
C
Night Bell
2 MF
Trunk Jack
Sleeve
Trunk Line
Q
Tip
m
Ring
30 Ohms
g_3
Branch Exchange
Sleeve
Ans. Jack
Tip
Ring
Line Lamp
L
R_2
R
i
Cut Off Relay
j
Line Relay
B
Main Exchange
g_2
Calling Plug
Ring
a
Branch Substation Line
Line Signal
E
S
80 Ohms
Night Bell
Branch Substation
600 Ohms
O
v
To Gen.
Sleeve
h
Ringing Key
n
Tip
To Gen.
Ans. Plug
To Gen.
Ringing Key
To Gen.
Sleeve
J
Tip
Line Circuit at Branch Exchange
B
Listening Key
Rec.
Cut Off Relay
R_1
Y
40 Ohms
Ret. Coil
2MF
Sec
Induction Coil
Prim.
e
x
u
f
10 MF
C'
B_1
600 Ohms
W
40 Ohms
Z
g_1
2MF Condenser

FIG. 17

operator answers with the back, or answering, plug of the cord circuit, thereby connecting the branch-exchange battery B_1 or other source of current, through Z–e–n to the tip conductor and through Y–f–h–to the sleeve conductor. The operator throws the listening key and learns the connection desired. The required station is signaled by means of the front, or calling, plug. If both stations are private-branch stations, the cut-off relay R_1 in the cord circuit is not operated, because the rings or thimbles of both local jacks are insulated, as shown at J, and not grounded. Current for talking purposes is furnished to the connected instruments through the 40-ohm retardation coils Y, Z and relay contacts f, e The supervisory signal O is always under the control of the instrument connected with the answering cord, because current can only flow through O by way of B_1–Z–e–n–tip of answering plug–line circuit–sleeve of answering plug–O–h–f–Y. Hence, the disconnect signal is not given until the receiver is hung up at the station at which the call originated.

56. If the subscriber at the branch substation desires a connection through the main exchange, the operator will insert the calling plug in a trunk jack Q associated with a trunk circuit. Current then flows through B_1–g_1–g_3–30-ohm resistance m–ring of trunk jack Q and calling plug–a–R_1–B_1; thus operating the cut-off relay R_1. This circuit is shown in Fig. 18 (b). Current then flows from the main-exchange battery B, Fig. 17, through g–g_1–Z–x–W–h–sleeve of calling plug and trunk jack–i–R, thereby operating the relay R and lighting the trunk-line lamp L at the main exchange. Some current also flows through B–j–tip side of trunk line and private-branch cord circuit–branch substation–sleeve side of line and private-branch cord circuit–supervisory signal O to h, and if B exceeds B_1 in voltage, some current also flows through g_2–g_1–B_1–Y–u–v–h, where the currents unite and flow through the sleeve side of the circuit–i–R back to B. The supervisory signal O is energized as long as the receiver at the originating branch substation remains off the

hook. When the main-exchange operator answers by inserting a plug in the answering jack, the main-office cut-off relay R_2, being connected through the ring side of the cord with the ungrounded terminal of the main-office battery, cuts off the line relay R and battery B and connects the battery B_2, as shown at the left-hand side of Fig. 18 (a), through impedance or repeating coils, as the case may be, in

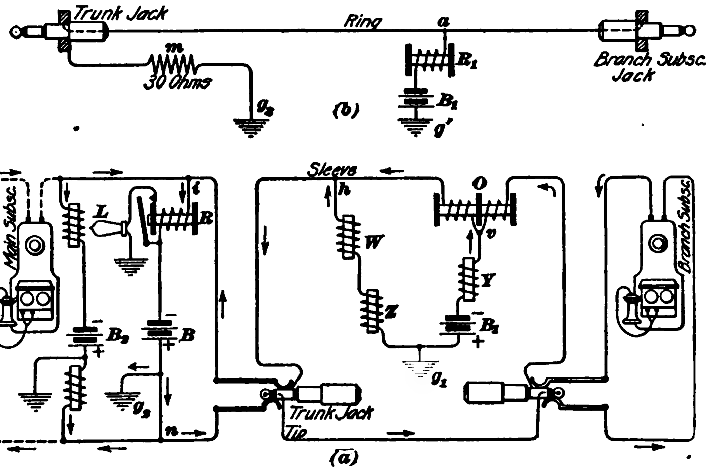


FIG. 18

the main-office cord circuit across the sleeve and tip conductors. The complete tip and sleeve circuits, omitting unnecessary details, are shown in Fig. 18 (a), except that the circuit containing the battery B and relay R is now open. B and B_2 are the same battery. When the receiver at the branch substation is hung up, the supervisory signal no longer receives enough current to remain energized, and the operator recognizes this as a disconnect signal and restores the plugs to their normal positions. The substitution of the tubular drop D, Fig. 17, and condenser C across the trunk circuit, causes the operation of the proper supervisory disconnect signal in the main-office cord circuit, thereby notifying the main-office operator that the trunk circuit to the branch office is no longer being used, and she can remove the plug in the answering-trunk jack.

57. Calls from the main office to the private-branch exchange are put through as follows: The operator at the main exchange rings on the trunk line and thus throws the tubular drop *D* at the branch exchange. The condenser *C* is connected in series with the trunk drop in order to prevent the constant flow of current from the main-office battery through the line and tubular drop, which would cause the line relay *R* and lamp *L* at the main office to be continuously energized. The insertion of this condenser makes it necessary for the central-office operator to ring over the trunk in order to operate the tubular drop.

The branch-exchange operator answers all incoming calls over the trunks and completes all outgoing calls over the trunks with the front, or calling plug, and consequently, the supervisory signal *O* is always under the control of the branch station. The 10-microfarad condenser C' bridged across the battery B_1 reduces the cross-talk.

PRIVATE-BRANCH CENTRAL-ENERGY EXCHANGE NO. 2

58. A private-branch central-energy exchange, supplied with battery and ringing current through two pair of No. 19 cable wires, is shown in Fig. 19. The cord circuit is adapted for both local and trunk connection and arranged so that the operator may, or may not, control the connection between a branch- and main-office subscriber. The control key used by the operator to control a connection is shown at *k*. The private-branch exchange is treated in exactly the same manner as a main-office subscriber, as far as the operation at the main exchange is concerned. The resistance of the long battery leads and the consequent drop in potential produced by the current tend to produce cross-talk between the various cord circuits that happen to be in use at the same time, but this is eliminated by connecting a condenser of 20 microfarads capacity *C* across the battery terminals at the branch exchange. The sharp fluctuations that would otherwise be produced across the terminals *a b* seem to be smoothed out by the large condenser; at any rate, cross-talk is practically

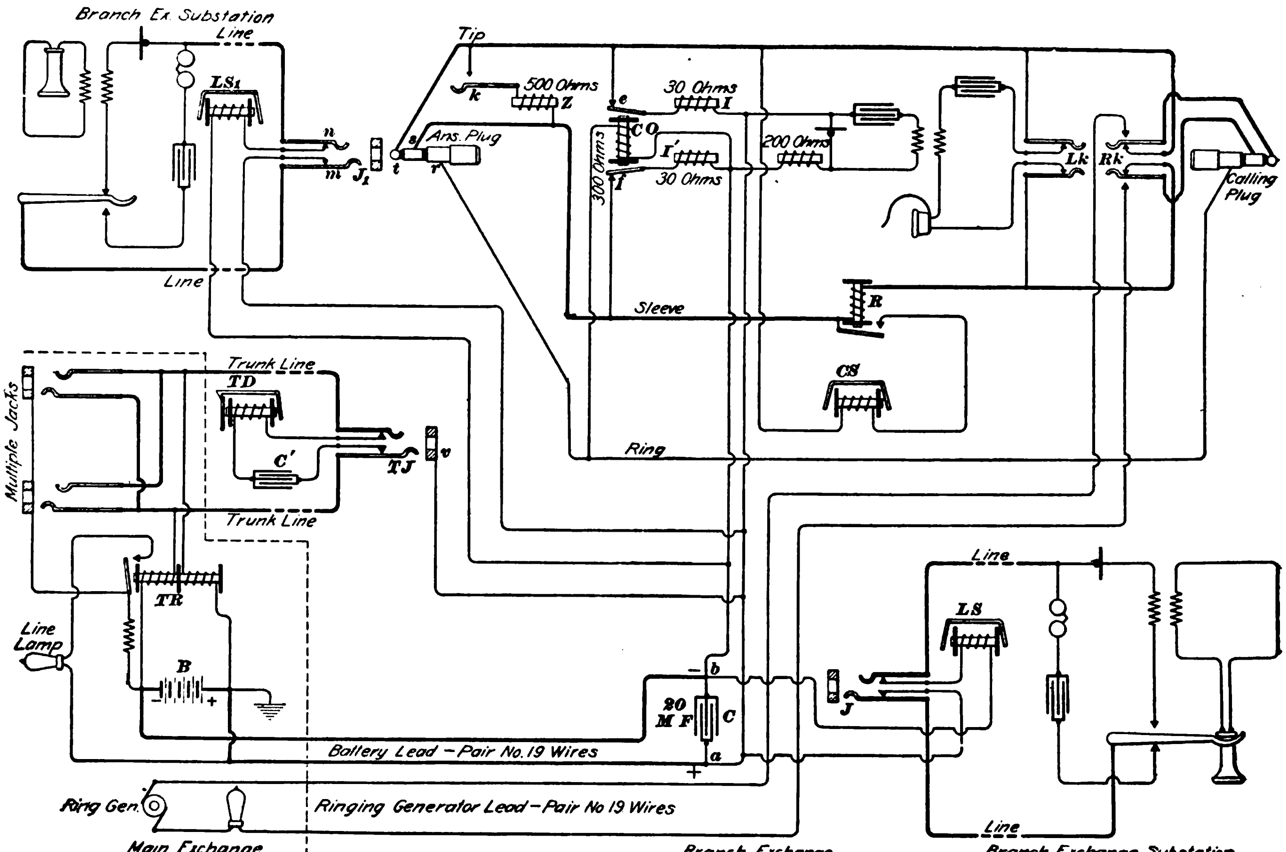

Branch Ex. Substation
Line
LS1
n
m
J1
Line
Tip
k
500 Ohms
Z
s
Ans. Plug
t
r
e
30 Ohms
I
CO
300 Ohms
I'
f
30 Ohms
200 Ohms
Lk
Rk
Calling Plug
R
Sleeve
CS
Ring
Trunk Line
TD
C'
TJ
v
Multiple Jacks
Trunk Line
TR
Line Lamp
B
Line
LS
J
-
b
20 M F
C
a
+
Battery Lead - Pair No. 19 Wires
Ring Gen.
Ringing Generator Lead - Pair No 19 Wires
Main Exchange
Branch Exchange
Line
Branch Exchange Substation

Fig. 19

eliminated, and the transmission between subscribers is not appreciably affected. Current for ringing purposes is supplied from the main exchange through another pair of cable wires.

59. Operation of Trunk Line.—The trunk line, which is a two-way circuit, terminates at the main exchange in the same manner as an ordinary subscriber's line and is supplied with current through the two windings of the relay *TR*; each winding acts as an impedance coil during a conversation. The trunk line terminates at the branch exchange in an ordinary magneto, or so-called ring-down, drop *TD* and a condenser *C'*, which are cut out of the circuit when a plug is inserted by the branch-exchange operator in the trunk jack *TJ*. The main-exchange operator calls up the branch exchange in the same manner as she would any subscriber, that is, by inserting a calling plug in one of the multiple jacks and closing the ringing key, which will cause the shutter of the drop *TD* to fall. The branch operator responds by first closing the control key *k*, which bridges 500 ohms across the tip and sleeve stands, and then inserting an answering plug in jack *TJ*. This causes a supervisory signal to be displayed, thereby notifying the main-exchange operator that the branch operator has answered.

The insertion of the answering plug in the trunk jack allows current to flow from *a* through *v–r–C O–b*, thereby disconnecting the impedance coils *I I'* from the circuit. The branch operator completes the call by inserting the calling plug in the jack of the branch subscriber desired and closing the ringing key *R k*. The relay *R* and clearing-out signal *C S* are, in turn, energized when the branch subscriber takes down his receiver. Talking current for both the main and branch substations is supplied from the main exchange through the same pair of wires used for the conversation. When the branch subscriber hangs up his receiver, the relay *R* and then the clearing-out signal *C S* are deprived of current, and the falling of the target of *C S* notifies the branch operator of this fact.

60. Operation of Branch Line.—If a branch subscriber removes his receiver, current flows from *a* through *m*–line–substation–line–*n*–$L\,S_1$–*b*, thereby causing $L\,S_1$ to display its target. The operator responds by inserting an answering plug in jack J_1, thereby cutting $L\,S_1$ out of the circuit. Current can now flow from *a* through *I*–*e*–*t*–*n*–branch-exchange subscriber's circuit–*m*–*s*–*f*–*I'*–*b*. The call, if for another branch subscriber, is completed in the usual manner, no busy test being required, as this is not a multiple switchboard, and the ring strand of the cord is not then in use. Both subscribers are supplied with current from the main-exchange battery through one pair of No. 19 wires, and the impedance coils *I I'*, each usually of 30 or 50 ohms resistance.

If the branch subscriber calls for a main-office subscriber, the branch operator inserts the calling plug in a trunk jack *T J*. If the branch subscriber is holding his receiver, this alone will properly operate the main-office line signal; but if the branch subscriber requests the branch operator to secure the connection desired, to call him up when it is secured, and then hangs up his receiver, the branch operator must close the control key *k* as she inserts the plug in the trunk jack, in order to operate the main-exchange line lamp. Current then flows from *a* through *v*–*r*–*C O*–*b*, thereby operating the cut-off relay *C O*, which disconnects the impedance coils *I*, *I'* from the cord circuit, thereby causing both subscribers' instruments to be supplied with current from the main-exchange battery and the same pair of line wires that connect the two subscribers' instruments.

Having obtained the main-exchange subscriber, the branch operator calls the branch subscriber. When the latter takes down his receiver, the branch operator is notified, because the relay *R* and clearing-out signal *C S* become energized, thereby causing the latter to display its target, which is a signal for the branch operator to open the control key *k* if she does not wish to longer control the main-office supervisory signal.

When the conversation is finished and the branch subscriber hangs up his receiver, signals are given at both exchanges

—at the main exchange the supervisory lamp lights, and at the branch exchange the clearing-out signal *CS* drops its target because it no longer receives current. Hence, both operators will disconnect the circuits.

61. If the operator desires to retain control of the main-office circuit, she leaves the control key *k* closed during the conversation, during which time the high impedance of the coil *Z* prevents any perceptible loss in efficiency.

At night, when no branch-office operator is required, a number of branch subscribers may be left connected through the cord circuits with the main exchange. For instance, if there are three trunk lines, three subscribers may be left connected to the main exchange. By having several trunk jacks in multiple with each trunk line, as many subscribers could be connected with the main exchange as there are cord circuits at the branch switchboard. Of course, a number of telephones would then be in parallel in each group, but this would be satisfactory enough for night service.

STERLING PRIVATE-BRANCH SWITCHBOARD

62. In Fig. 20 is shown the line and cord circuits of a private-branch exchange installed by the Sterling Electric Company in 1903. The board has a capacity of about fifty lines although it is not equipped with that many. This board is supplied with all current, except for ringing the bells, from the storage battery *B*, which is located in the city-exchange building, at a distance of about 900 feet. The conductor *a b* consists of three tip wires and *c d* of three sleeve wires of three pair of ordinary cable conductors. The line and cord circuits are very simple, only one double-wound relay *R* being required for each line circuit, while the cord circuits are free from coils of any kind, except one supervisory pilot relay *Sp r*, which is common to all the cord circuits. There are condensers *C*, *C'* in the sleeve and tip conductors of each cord circuit and the usual listening and ringing keys. The ringing generator is a Warner pole changer. The cord and

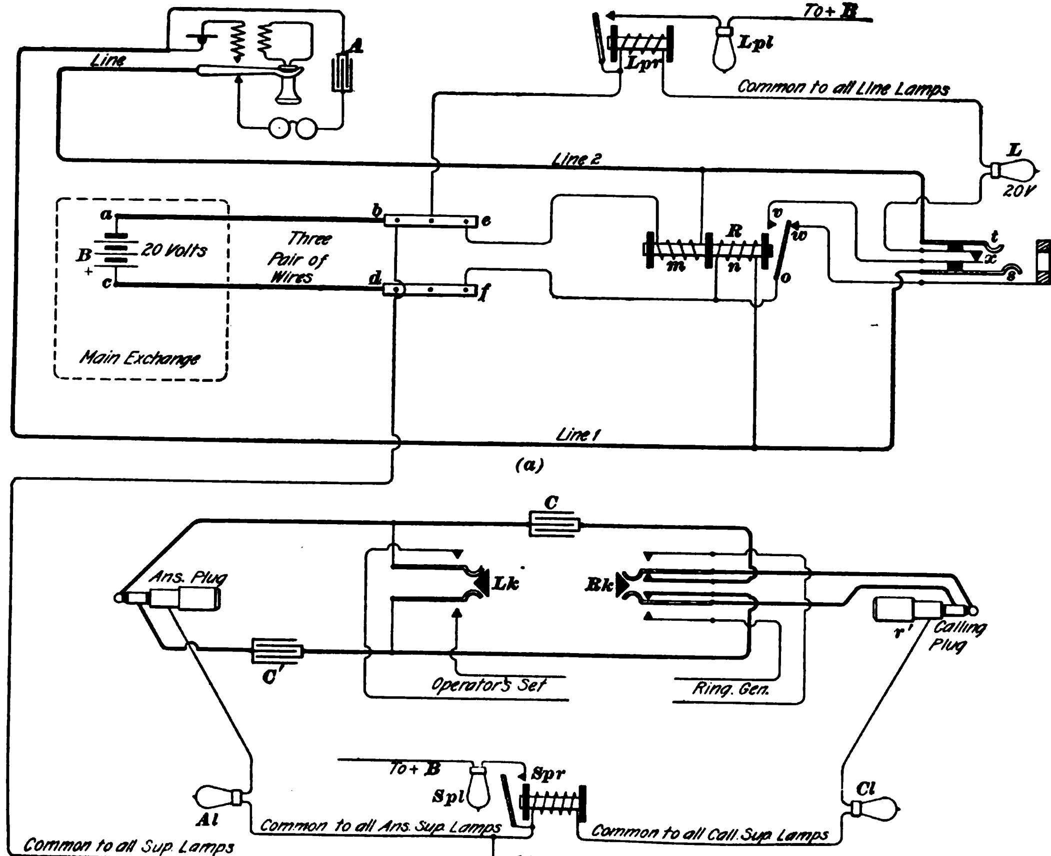

To + B
Lpl
Lpr
Common to all Line Lamps
A
Line
L
20V
Line 2
a
B
+
c
20 Volts
Three
Pair of
Wires
b
e
d
f
Main Exchange
m
R
n
v
w
o
t
x
s
r
Line 1
(a)
C
Ans. Plug
Lk
Bk
r'
Calling
Plug
C'
Operator's Set
Ring. Gen.
To + B
Spl
Spr
Al
Cl
Common to all Ans. Sup. Lamps
Common to all Call. Sup. Lamps
Common to all Sup. Lamps
(b)

Fig. 20

line circuits are of the three-conductor variety. The jack has an extra pair of contacts *x*, which are separated when the plug is inserted in the jack. It is not a multiple board and hence no busy test is required. It is attended to by the regular telegraph operator and no means of connection is provided between the telephones terminating at this board and the regular city exchange. For communication with subscribers of the city exchange, there are a number of telephones located in various parts of the buildings and connected directly with the city exchange. All lamps operate on 20 volts.

63. Operation.—When a subscriber removes his receiver from the hook, current flows through *f*–winding *n*–line *1*–transmitter–primary winding of the subscriber's induction coil–hook switch–line *2*–winding *m*–*e*; this causes the line relay *R* to attract its armature and current flows through *f*–*o*–*v*–*x*–*L*–*L p r*–*b*, thus lighting the line lamp *L*, energizing the line pilot relay *L p r* and lighting the line pilot lamp *L p l*. On inserting the answering plug in the jack, the contacts *x* are separated, hence the line lamp goes out. The contact *w*, being open, the answering supervisory lamp *A l* cannot light. Closing the listening key enables the operator to converse with the party at *A*.

The substation desired is called by inserting the calling plug in the proper jack and closing the ringing key *R k*. Until the receiver at the desired station is removed from its hook, current flows through a circuit similar to *f*–*o*–*w* to the ring of the jack associated with the desired line–ring *r'* of the calling plug–*C l*–*S p r*–*b*, thereby lighting the calling supervisory lamp *C l*, energizing the supervisory pilot relay *S p r*, and lighting the supervisory pilot lamp *S p l*. As the receivers at the substations are hung up, the line relays in the corresponding line circuits release their armatures, thereby closing the back contacts *w* and thus lighting the corresponding supervisory lamps *A l* and *C l*. All circuits are restored to normal condition, in which no battery current is consumed, by the removal of the plugs from the jacks.

COMMON-BATTERY SIGNALING SYSTEMS

LINE AND SWITCHBOARD CIRCUITS

1. In **common-battery signaling systems**, the subscriber's line and clearing-out signals are operated by the removal and hanging up, respectively, of his receiver. The signaling current is obtained from a battery, common to all circuits, located at the exchange, but current for the transmitter is furnished by a primary battery in each subscriber's instrument. There are usually two clearing-out signals in each cord circuit—one on the answering side, operated by the calling subscriber when he hangs up his receiver, and the other on the called side, operated by the called subscriber when he takes down and hangs up his receiver. By the use of supervisory signals, the operator is at all times aware of the condition of any two lines while connected together for conversation. Systems involving these two features, but retaining primary batteries in each subscriber's instrument for the operation of his transmitter, are termed *common-battery signaling*, *common-battery supervisory*, or *central-energy call*, *systems*.

2. Common-battery signaling switchboards may be operated more rapidly than ordinary magneto-switchboards because all signals are self-restoring and the operator supervises connections without the necessity of listening on the circuit. They possess many of the good features of full central-energy systems and the service is sufficiently rapid except for large and busy exchanges.

They are, however, open to the objection that the battery is retained in the subscriber's station; also, that the signal current passes through the talking apparatus (secondary of induction coil and receiver winding), thereby cutting down the efficiency of the receiver by either weakening the permanent magnets or strengthening them to such a degree that the diaphragm is buckled too much to work well. The subscriber's telephone is more complicated, costs more, and will cause greater trouble than the full central-energy telephone.

These systems are being replaced by full lamp-signal central-energy circuits. The modern practice is to put the rural or extremely long lines on magneto-positions that are provided with drops and jacks. This eliminates the central battery from such lines and allows a much better service, as slight troubles, such as high-resistance grounds and crosses, that would give a permanent signal on central-energy systems will not prevent calling on a magneto-line. It is now conceded that it is not good engineering or operating to put common battery on any lines not easily reached by the troubleman; otherwise, in bad weather, when it is difficult to remedy such troubles, these lines may be tied up for days at a time.

3. A **toll line** is a line between two exchanges usually located in different towns or cities, the name being derived from the fact that it is usually the custom to charge a fee, or toll, each time the line is used. Such circuits are also termed long-distance, or *L D*, lines. In rural districts, toll lines sometimes terminate in an exchange at one end only. In this case, a number of telephones belonging to farmers are connected with the same toll line; but even when the toll line terminates in an exchange at both ends, a number of farmers' telephones are frequently connected to it.

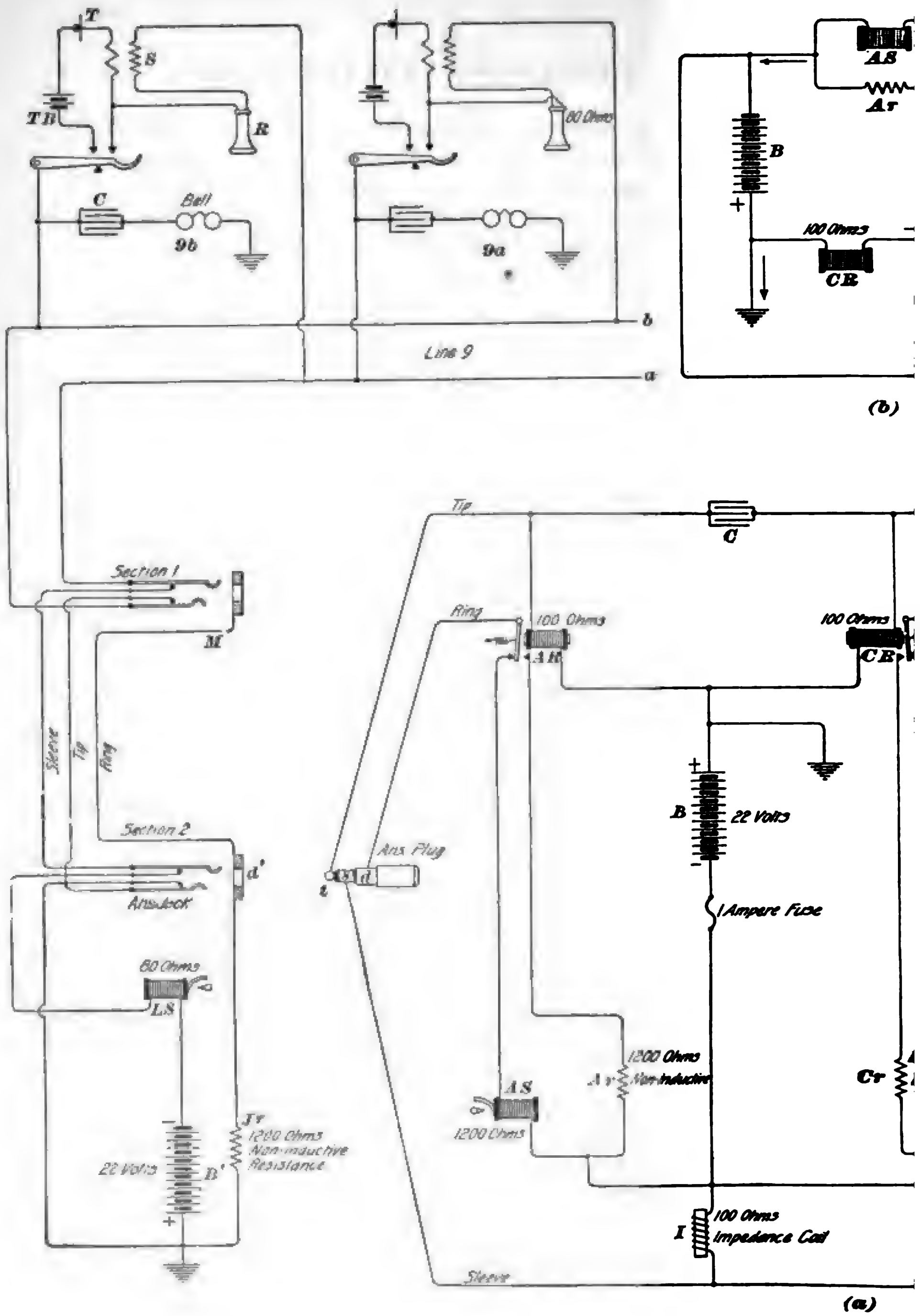
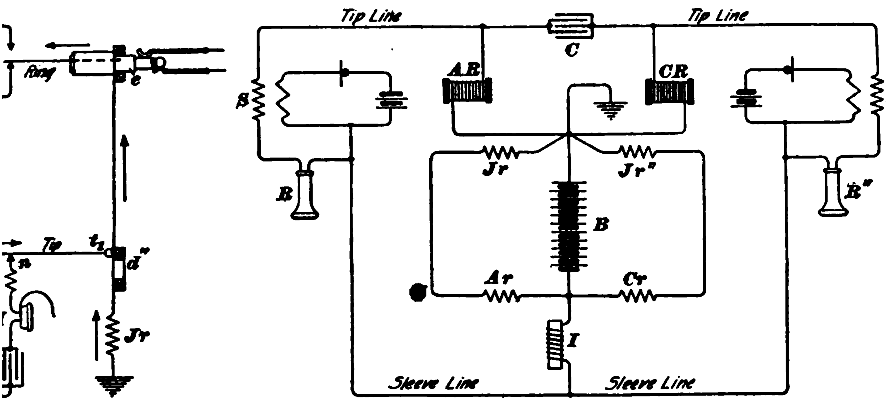
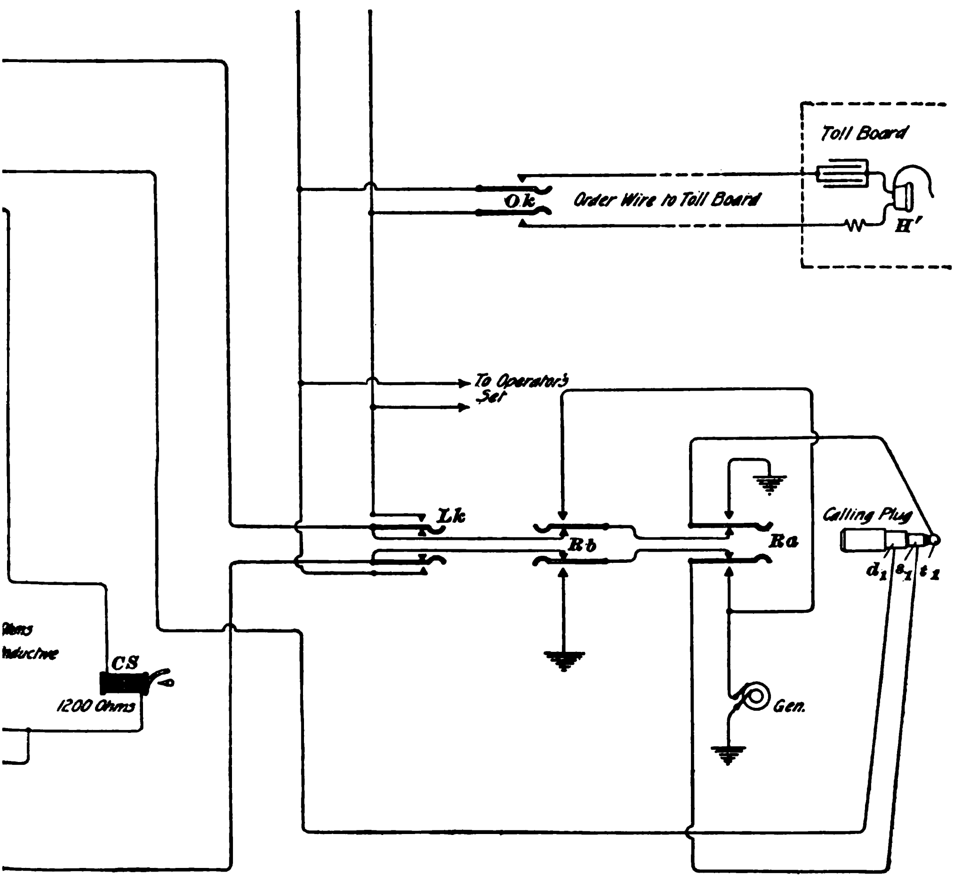


FIG. 1. CENTRAL UNION CO


Tip Line
Tip Line
C
AR
CR
S
S"
B
B"
Jr
Jr"
B
Ar
Cr
I
Sleeve Line
Sleeve Line
Ring
e
Tip
t_1
d"
n
Jr

(c)


Toll Board
Ok
Order Wire to Toll Board
H'
To Operator's Set
Lk
Rb
Ra
Calling Plug
d_1
e_1
t_1
CS
1200 Ohms
Gen.

CENTRAL-UNION COMMON-BATTERY SIGNALING SYSTEM

4. The multiple common-battery signaling system used for moderate-sized exchanges by the Central Union Telephone Company, which is a licensee of the Bell Company and operates exchanges in some of the Middle States, is shown in Fig. 1 (*a*). It is sometimes called a double supervisory multiple system, because two supervisory signals are used in each cord circuit. Only the features peculiar to this system will be considered. The arrangement of the spring jacks and line signal constitute what is called a series-multiple line circuit, because the jacks and signals are connected in series so that the insertion of a plug in a jack will entirely disconnect the line signal, battery, and all other spring jacks on the battery side of the jack in use. It has the disadvantage that the contacts in several jacks are usually in the line circuit while talking, and that there are five wires running into each jack. At the subscribers' stations, regular bridging telephone instruments, or the connections shown at the subscribers' stations in this figure, may be used. As shown here, the instruments may readily be changed, by omitting the talking battery *TB* and altering the connections slightly, so that they may be used on a full central-energy system. For that matter, any modern central-energy system will permit the use of local-battery telephones on its lines, provided that condensers are placed in series with the bridging bell. The plugs have three contacts *t*, *s*, *d* that engage corresponding contacts in the jacks.

5. Two-Party-Line Service.—Two stations may be connected to the same pair of line wires and the operator may ring either bell without causing the other to ring. For instance, by inserting the calling plug in jack *M* and closing the ringing key *R a*, only the bell of subscriber *9 a* will ring; similarly closing *R b* will ring only the bell of subscriber *9 b*. The ringing current returns from the subscriber's station through ground to the exchange in each case. Only an

ordinary alternating-current ringing generator is required. More subscribers are often connected to the same line circuit; in which case, a system of signals is required and the depression of one ringing key will ring all the bells connected between one side of the line and the ground. If only one telephone instrument is to be used on one pair of line wires, the subscriber's bell and condenser would be connected directly across the two line wires, instead of being grounded, and the depression of either ringing key would ring the bell.

6. Operation.—When a subscriber takes down his receiver, current flows from B' through the jack-springs, hook switch, receiver R, secondary coil S, jack-springs, and line signal $L\,S$, thereby causing the line signal $L\,S$ to raise its shutter. When the answering plug is inserted in the answering jack belonging to this line, the circuit through the line signal and battery is opened at the jack and the shutter falls. Sufficient current now flows from $+B$ through the answering supervisory relay $A\,R$, subscriber's receiver and secondary coil and the impedance coil I to $-B$ to energize the relay $A\,R$ and hence prevent the answering supervisory signal $A\,S$ from receiving current. However, there is a closed path from $-B$ through the non-inductive resistance $A\,r$, ring contacts of plug and jack d, d', respectively, and non-inductive resistance $J\,r$, so that all the jacks belonging to that line will give a busy-test click if tested at any section while the line is in use.

Having ascertained the subscriber wanted, the usual busy test is made with the calling plug: and, if not busy, the connection is completed and the proper ringing key, either $R\,b$ or $R\,a$, depressed. The circuits involved in the busy test are shown in Fig. 1 (b). The mere removal of a receiver from the hook does not make a line test busy: a plug must be in one of the jacks. For instance, e represents a plug in a jack of line 2, and the tip t_1 of a calling plug belonging to a cord circuit at some other section of the multiple switchboard is being touched to the ring d'' of a jack belonging to the busy

line 2. If there were no plug *e* in the jack, the operator's receiver *H* would have applied to it the full potential of the battery *B*, but when current can flow through *e* and *A r* back to *B*, the fall of potential through *CR* suddenly lowers the potential of point *n*, and causes a click in the operator's receiver *H* when the tip t_1 first touches the ring d''.

The calling supervisory signal *CS* will receive current and show its shutter until the called subscriber takes down his receiver, thereby allowing the calling supervisory relay *CR* to receive current that will cause it to open the circuit through *CS*. As each subscriber hangs up his receiver, the corresponding relays, *AR* and *CR*, will be deprived of current and hence the corresponding supervisory signals *AS* and *CS* will show their shutters.

7. The condition of the circuit while conversing is shown in Fig. 1 (*c*). Except for the wiring of the subscriber's instrument, it is practically a full central-energy system. The receiver *R* being directly in the line circuit, it should be connected so that the current passing through it from the battery *B*, which is, however, very small, tends to magnetize the cores in the same direction as the permanent magnet. The condenser *C* is necessary for the independent operation of the answering and calling supervisory signals, and does not prevent the talking currents from readily passing from one line to the other. The impedance of the supervisory relay *AR* and the impedance coil *I* is sufficient to prevent the short-circuiting of the talking currents. The impedance coil is necessary to preserve the balance of the circuit, causing the battery and its grounded terminal to be practically in the center of this branch across the cord circuit. The busy test is said to have given some trouble in this system.

8. The **toll trunk circuit** used in the same exchange is shown in Fig. 2. If subscriber *9* calls for connection with a toll line, the answering operator closes her order-wire key *O k* and states the line desired. The toll operator in reply states the number of trunk to use. The answering operator

withdraws the answering plug of her regular cord circuit from the calling subscriber's jack *J* and inserts, in its place, the trunk plug in which the trunk circuit specified by the toll operator terminates. This will operate, at the answering operator's position, the cord signal *T* associated with that

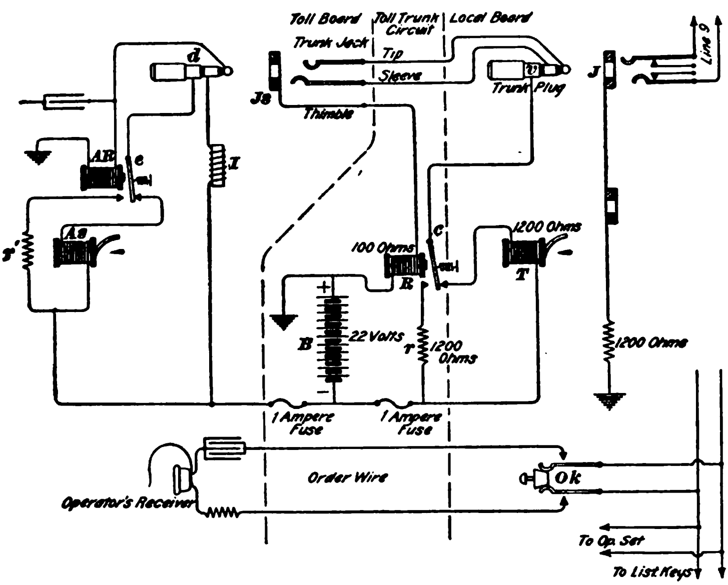


FIG. 2

trunk circuit. All No. *9* line jacks will also test busy. As soon as the toll operator inserts one plug of her cord circuit in the trunk jack *Js* in which that trunk terminates at her board, current flows from $+B$ through the 100-ohm relay R–Js–d–e–r', or *A S*, to $-B$ and cause armature *c* to be attracted, which substitutes the resistance *r* in place of the signal *T*, so as to keep the busy test on the line jacks and, by the restoration of the signal *T*, to notify the original operator that the call is being properly attended to by the toll operator. When the conversation is finished and the subscriber's receiver hung up, *A R* releases its armature, *A S* shows its shutter, and the toll operator who supervises the connection removes her plug from the trunk jack; relay *R*

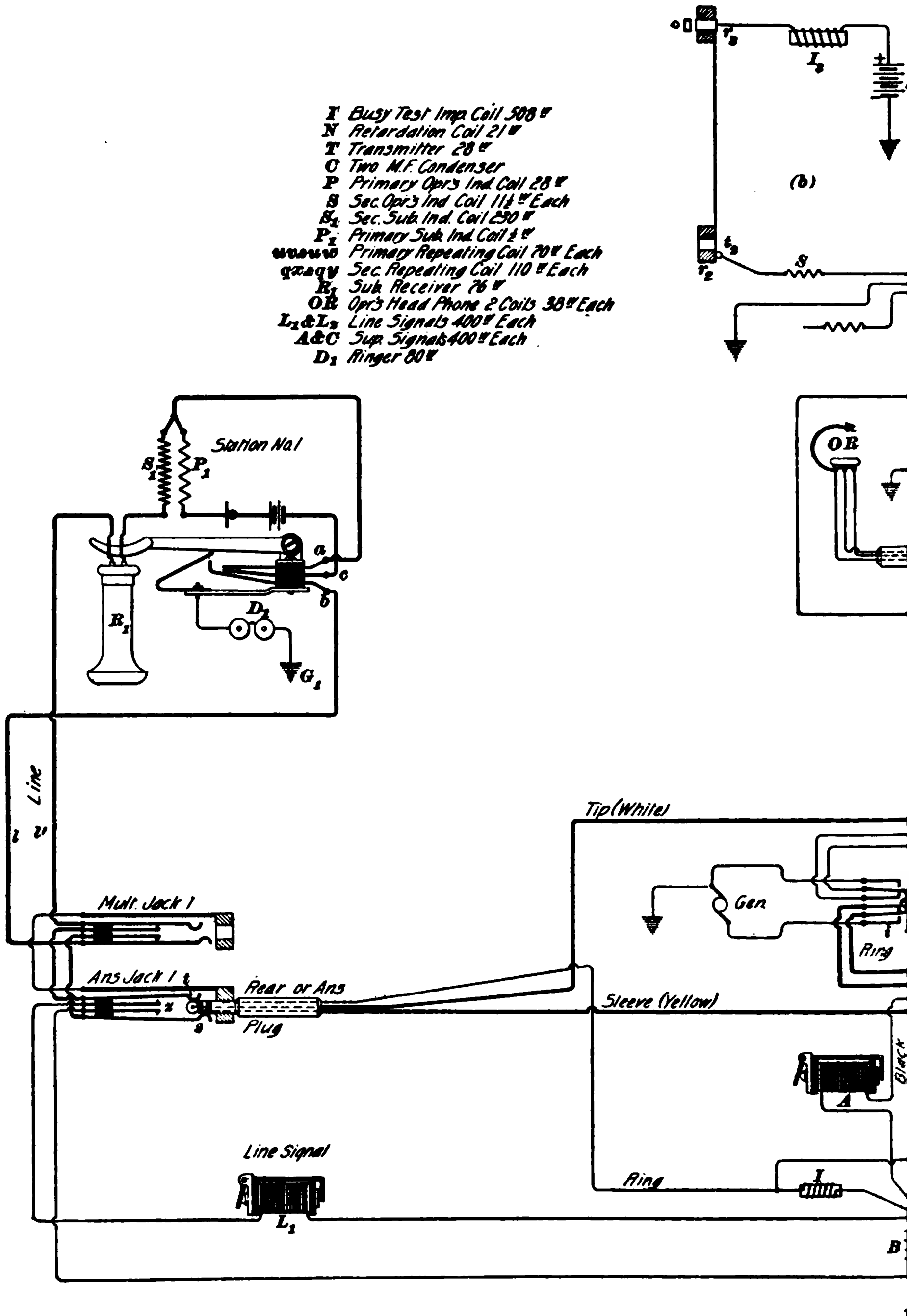
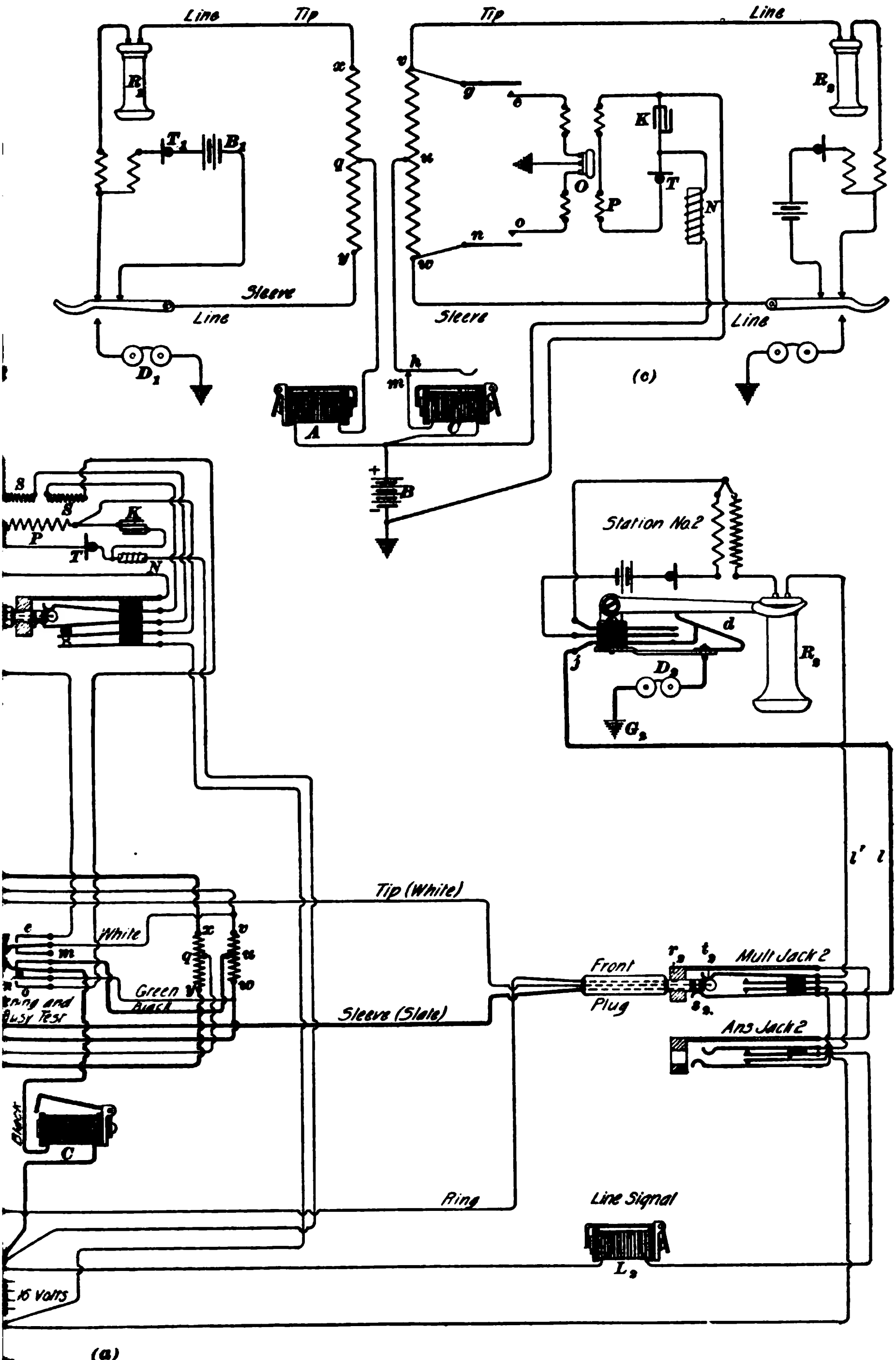


FIG. 8. NORTH COMMON-B



Line
Tip
Sleeve
Line
(c)
Station No.2
Tip (White)
White
Green
Black
Sleeve (Slate)
Front
Plug
Mult Jack 2
Ans Jack 2
Ring
Line Signal
16 Volts
(a)

will then release its armature, the trunk signal T will display its target, and the original operator is thus notified to withdraw the trunk plug from the subscriber's jack.

NORTH COMMON-BATTERY SIGNALING SYSTEM

9. The North Electric Company's common-battery signaling system is shown in Fig. 3. At Sandusky, Ohio, where this system was installed and successfully used, the board had an ultimate capacity of 2,400 lines, about 1,000 of which were in use in 1903. No magnetic generator is required in the subscriber's instrument and bell D_2 is connected between the ground and line l, through springs d, j, when the receiver rests on the hook, as shown at station No. *2*. When the receiver is lifted off the hook, as shown at station No. *1*, the bell is disconnected and receiver R_1 and secondary winding S_1 are connected across the two line wires, through springs a, c, b,. and the transmitter circuit is closed through springs a, c.

The line and supervisory signals L_1, L_2, A and C are so-called *target signals*, one of which will be shown in the next Section. The signal is restored by gravity, when the current ceases to flow. The normal adjustment of each line signal, which is equipped with a removable numbering plate, is for working through 1,500 ohms at a pressure of 16 volts, but they can be adjusted to work through a much higher resistance where special line conditions require it.

The spring jacks and line signals are arranged in a series-circuit very much resembling that shown in Fig. 1. When the receiver at station No. *1* is lifted off the hook, current flows from $+B$ through L_1–contacts in the answering and multiple jacks–l'–R_1–S_1–a–b–l–contacts in multiple and answering jacks to $-B$, thereby operating the line signal L_1. On the insertion of the answering plug in answering jack *1*, the line signal L_1 is restored because the circuit through it is broken at the jack-springs z; and the closing of the contacts g, e and n, o by means of the listening key allows the subscriber and operator to converse through the repeating coil xy–vw. [See also Fig. 3 (c).] To use a repeating coil

in each cord circuit in this manner is rather unusual and seems objectionable at first; nevertheless, repeating coils can now be made that are very satisfactory for talking purposes and the arrangement here is such that the circuits are very evenly balanced, electrically, while a conversation is being held. Each winding of the repeating coil has the same number of turns although not the same resistance. This inequality in resistance makes no difference in this system, because the line circuits would be apt to vary more or less in resistance. If desirable, the coil can be connected so that each half will have the same resistance and the same number of turns.

10. The **busy test** is made in the usual manner. When the listening key is closed, the circuit is open between m, h, thereby breaking the connection between the calling supervisory signal C and the middle u of one winding of the repeating coil; this is necessary, otherwise a click will be produced in the operator's receiver, even if the line is not busy. If the line is busy, a click will be produced in the operator's receiver as she touches the tip t_1 of a calling plug to the ring r_2 of the busy-line jack, due to current flowing through one half of the operator's receiver to ground, the circuits involved being shown in Fig. 3 (b). If the line is not busy, there will be no connection from r_2 through I_2 to $+B$. The listening key is restored after making the busy test.

11. The insertion of the calling plug into multiple jack *2* will cut off answering jack *2*, and line signal L_2. The closing of the ringing key connects the ringing generator directly across the tip and sleeve strands of the calling plug and disconnects the winding $v\,w$ of the repeating coil from the calling plug. Current flows from the ringing generator through contact springs i, f–the sleeve conductor–s_2–line l–contact springs j, d–bell D_2–ground G_2 to the ringing generator. On releasing the ringing key, current flows from $+B$ through C–h–m–u–w–e–f–s_2–l–j–d–D_2–G_2–G to $-B$, and causes the supervisory signal C to display its number until subscriber No. *2* breaks the connection through the bell to ground by

removing the receiver from the hook. The condition of the circuits during conversation is shown in Fig. 3 (*c*). The operator's circuit is added to this figure, as it is not shown as clearly in Fig. 3 (*a*). When the conversation is finished the hanging of the receivers R_1, R_2 on their hooks will operate the supervisory signals *A* and *C*, respectively. In series with each operator's transmitter *T* is an impedance coil *N*; it is used to limit the current through the transmitter and also to prevent cross-talk between the various operator's circuits, which it does by confining the rapid fluctuations to the circuit *T-K-P*. The condenser *K* not only helps to prevent cross-talk but also improves the articulation of the operator's circuit. As the resistance of the transmitter increases, the potential across the condenser increases, and consequently the charge on the condenser increases; and when the transmitter decreases in resistance, the potential across the condenser decreases, and the surplus charge on the condenser rushes through the transmitter, which offers the smaller resistance, thus making the change in the strength of the current through the primary winding of the induction coil greater than would be the case without the condenser.

STROMBERG-CARLSON COMMON-BATTERY SIGNALING SYSTEM

12. Non-Multiple System.—A common-battery signaling system, made by the Stromberg-Carlson Telephone Manufacturing Company for use in small exchanges, is shown in Figs. 4 and 5. It is not a multiple switchboard system. It has given satisfaction for several years in, at least, one exchange consisting of a two-section switchboard, 400 subscribers, some party lines, and several toll lines. One section is common-battery signaling and the other includes both common-battery signaling and generator-call circuits with bridging and series-instruments. The battery at the exchange consists of two sets, each set containing twelve storage cells that are charged from a 110-volt electric-light circuit using a lamp bank as a resistance.

The common-battery signaling line and cord circuits are shown in Fig. 4. The line circuit is very simple and consists of a spring jack and electromagnetic, self-restoring, target signal L for each line circuit, and one line-pilot relay LP that serves for all lines.

13. Operation.—When a subscriber removes the receiver from the hook, current flows from the battery B through the line-pilot relay LP and the line signal L, thereby causing the line signal to display its target and the line-pilot relay to tap once a gong fixed on it, and to also ring the night-alarm bell V if the switch S is closed. During the day, the single tap of the relay on its gong will be sufficient to attract the attention of the operator if she does not happen to be at the switchboard or see the line signal operate. The operator answers a call by inserting the answering plug in the jack, thereby cutting out the line signal and line-pilot relay. Current then flows from the battery B_1 through the two windings of the clearing-out signal O to the subscriber's line circuit, thereby causing the clearing-out signal O to display its target, and also to open a local circuit containing the clearing-out pilot relay SP. On closing the listening key Lk, the operator may communicate with the subscriber. To prevent cross-talk between the operator's circuits and also to limit the strength of the current, two impedance coils I, I' are connected in each operator's primary circuit; the condenser C improves the transmission qualities of the operator's circuit.

Having obtained the number of the subscriber desired, the operator completes the call by inserting the calling plug in the proper jack and closing the ringing key Rk. The ringing machine may be a hand or power generator, or a pole changer. The buzzer in the ringing circuit sounds when the ringing current flows through the circuit. The closing of the ringing key opens the cord circuit between the battery B_1 and the calling subscriber's jack. The removal of the calling plug from its seat allows the plug switch Ps to close; this would operate the relay SP were it not that its

circuit is open at the armature contact of the clearing-out signal *O*, which is energized by current that flows through the answering side of the circuit. While the subscribers are talking, the battery B, sends current through both subscribers' line circuits, the two windings of the supervisory signal acting as impedance coils as well as energizing the clearing-out signal.

Both subscribers must hang up their receivers before the clearing-out signal is deprived of current; it then releases its armature and no longer displays its signal. Furthermore, the armature closes the circuit containing the clearing-out pilot relay *SP*, causing the latter to tap its gong, and the bell V' to ring if the switch S' is closed. When the operator takes down the connections and restores the calling plug to its seat on the cord shelf, the plug switch *Ps* is opened, thus preventing the current from flowing through the clearing-out pilot relay *SP* when the cord circuit is not in use.

14. In order to avoid complicating the diagram, two bells V, V', two batteries B_3, B_4, and two switches S, S' are shown in this figure, but there is really only one of each, and they are connected as shown in Fig. 5. For B, B_1, and B_2, the same storage battery is used, but for B_3 and B_4, dry or Leclanché cells may be used. The line- and supervisory-pilot relays are pony telegraph relays with a gong and tapper added; such relays are used in some district messenger telegraph systems and are made by the Western Electric Company and other makers of telegraph instruments.

The **order-wire circuit** between two sections of the switchboard is shown in Fig. 4. If the operator at one section desires to communicate with an operator at another section, she does so by closing the order-wire key *Ok*, thereby connecting her telephone set with the other operator's telephone set, as may be seen by tracing the circuits. The operator at the other section, on the other hand, may communicate with the operator at this section by closing the order-wire key *Ok'*. This order-wire circuit requires four wires between the two operators; however, it is a two-way circuit and hence may be used in both directions.

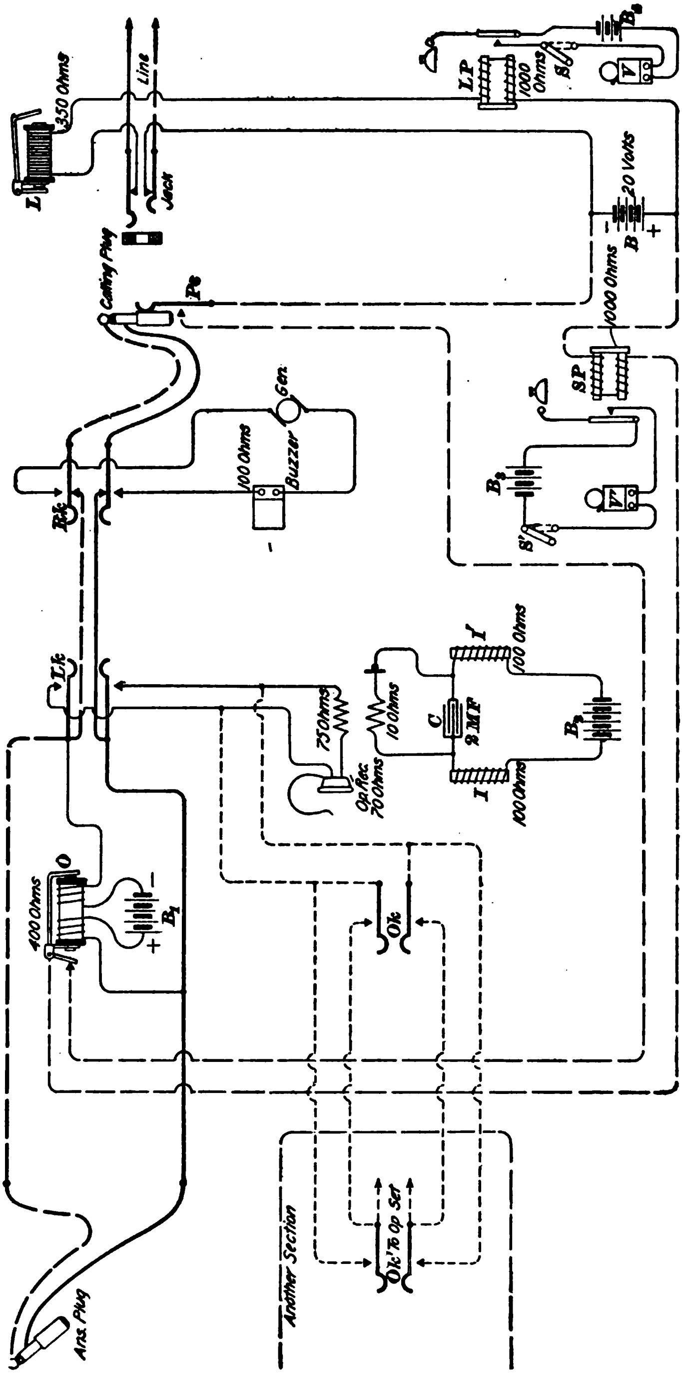
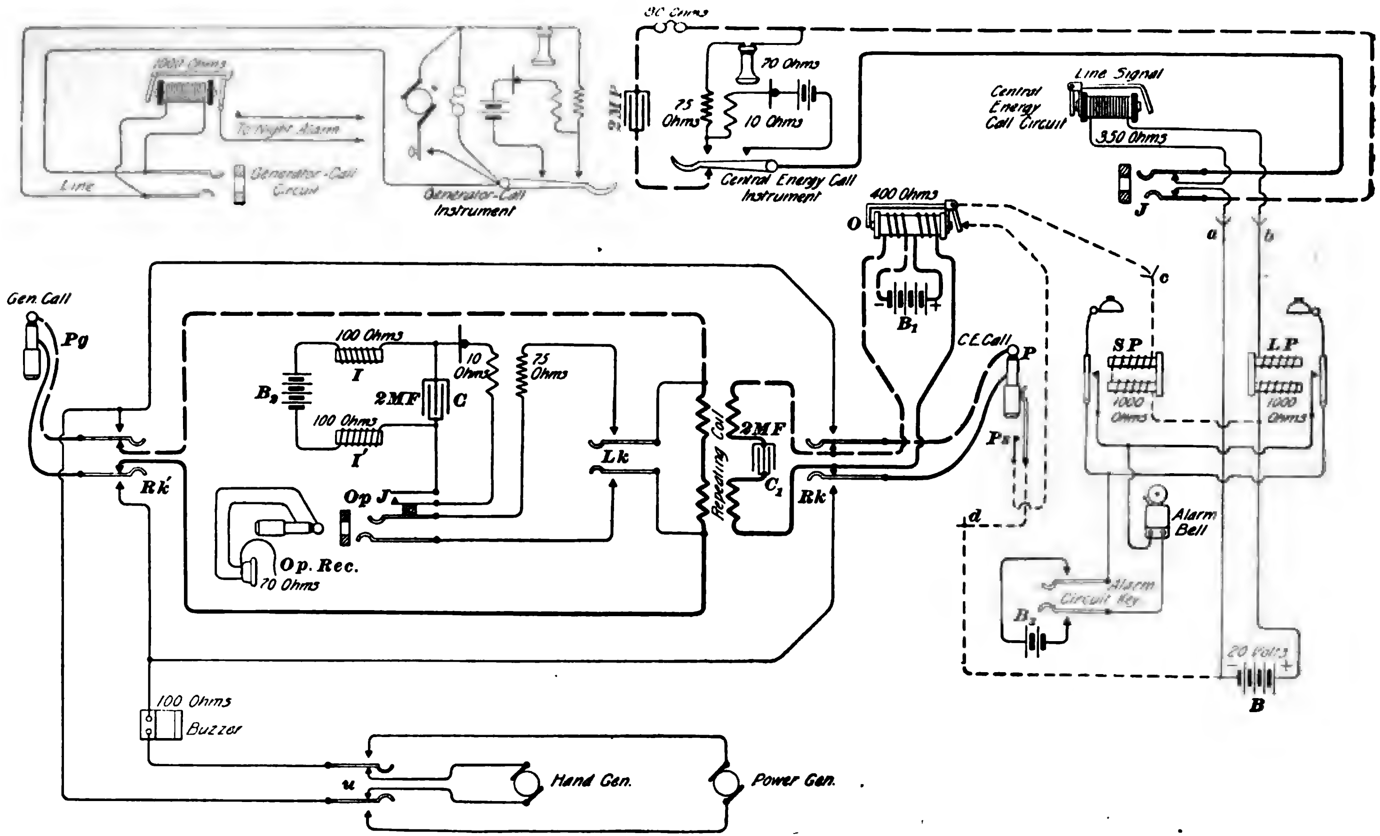

350 Ohms
Line
Jack
Calling Plug
LP
1000 Ohms
20 Volts
1000 Ohms
SP
Gen.
100 Ohms
Buzzer
Lk
75 Ohms
10 Ohms
C
8 MF
100 Ohms
Op Rec
70 Ohms
400 Ohms
Ok
Another Section
Ok' To Op Set
Ans. Plug

Fig. 4



1000 Ohms
To Night Alarm
Line
Generator-Call Circuit
Generator-Call Instrument
2MF
70 Ohms
75 Ohms
10 Ohms
Central Energy Call Instrument
Line Signal
Central Energy Call Circuit
350 Ohms
J
a
b
400 Ohms
O
c
B1
C.E.Call
P
SP
1000 Ohms
LP
1000 Ohms
Gen. Call
Pg
100 Ohms
I
B2
2MF
C
10 Ohms
75 Ohms
100 Ohms
I'
Lk
Repeating Coil
2MF
C1
Rk'
Op J
Rk
Ps
d
Alarm Bell
Op. Rec.
70 Ohms
Alarm Circuit Key
B3
20 Volts
B
100 Ohms
Buzzer
u
Hand Gen.
Power Gen.

FIG. 5

15. Circuits Between Generator-Call and Central-Energy-Call Telephones.—The modifications of the circuit shown in the last figure when it is necessary to connect together central-energy-call and magneto-generator-call instruments, are shown in Fig. 5. Details which were omitted from the last figure for the sake of simplicity are shown here. The modifications consist in connecting the two plugs together through a repeating coil and the use of a double ringing key Rk and Rk'. In other respects, the connections are practically identical with those shown in the last figure. The repeating coil is necessary to prevent current from the common battery B_1 from flowing through the magneto-generator-call instrument, and the condenser C_1 in the middle of one winding of the repeating coil is necessary to make the operation of the clearing-out signal O depend on the position of the hook switch in the central-energy-call instrument. The two ringing keys Rk and Rk' are placed close together and arranged so that pushing one handle in one direction sends the ringing current through the generator-call plug Pg, and pushing the same handle in the opposite direction sends ringing current through the central-energy-call plug P. At points a, b, the various line circuits are connected together and pass through one line-pilot relay LP and battery B. At the points c, d, the various clearing-out pilot circuits are collected together so as to pass through one clearing-out pilot relay SP and battery B. By means of the switch u either a hand or power generator may be connected to the ringing keys.

The operation of this circuit is practically identical with that given for the last figure, except that the operation of the clearing-out signal depends entirely on the position of the hook switch in the central-energy-call instrument, and the plug Pg must always be used when answering or calling a magneto-generator-call instrument, while the plug P must always be used for answering or calling a central-energy-call instrument, and for this reason a double ringing key is necessary.

The central-energy-call instruments can be converted into complete central-energy instruments and with the line and

cord circuits shown in Fig. 4 can be operated as a complete central-energy system. The subscribers' instruments were mostly old magneto-instruments; the generators were removed and the condensers inserted. The receivers were 70 ohms, the primary winding of induction coil 10 ohms, secondary winding 75 ohms, bell 80 ohms, and condensers 2 microfarads.

16. To Properly Connect a Receiver on Any Common-Battery Signaling System.—Connect the receiver to the subscriber's telephone as in any local-battery system and unscrew the cap of the receiver. If properly connected, the diaphragm will be held tightly against the poles of the receiver; if not, the diaphragm will be held lightly or not at all. This is a sure test for the proper polarity of receivers.

Another way is to call central. If the transmission is good, the receiver is properly connected; if distant, muffled, and weak, it needs to be reversed. If wrongly connected, the remedy is to reverse the connections of the receiver cord at the receiver or telephone.

TOLL AND TRUNK CIRCUITS

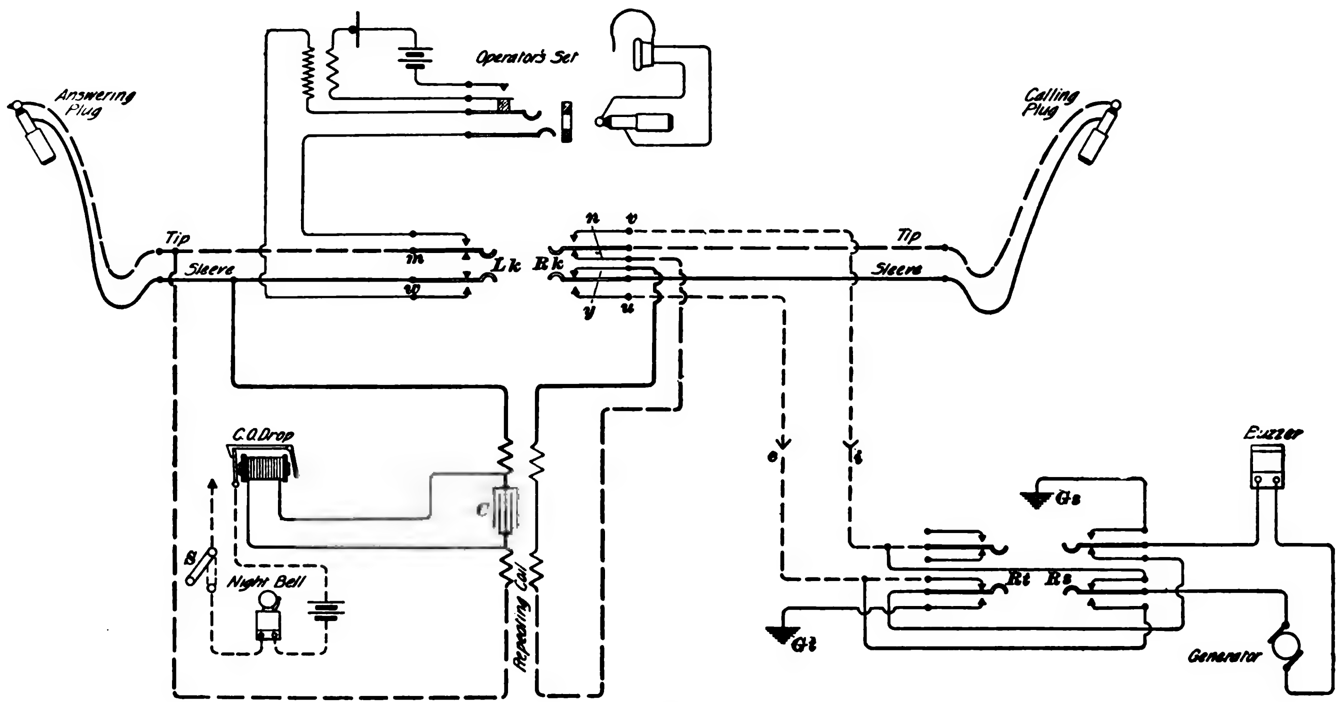
17. Toll Boards.—In most exchanges, the toll board is separate from the local board; and in some, it is in a separate room, trunks being provided between the toll and main boards. Sometimes, the toll board forms a part of the main board, or has attached to it a section of the multiple board; in other cases, the order from the subscriber, or *A*, operator is given over an order, or call, wire, to the toll, or *B*, operator; or, in large exchanges, to the recording, or assigning, operator. The operation is as follows: The subscriber calls the operator and asks to be connected to long distance; the operator presses the button marked toll or *L D*, giving the number of the calling subscriber, whereupon the recording, or toll, operator inserts one plug of her cord circuit in the subscriber's jack, which is among the multiple jacks before her, asks the subscriber his name and number, and also the name of the town, the name and number, or call, of

the party wanted, keeping a record of the same on the ticket. If the line desired is not busy, the toll operator will put through the connections at once; but usually the subscriber is told that he will be called as soon as the party desired is obtained. The duty of the recording operator is to take all calls from subscriber operators, get particulars of call, fill out the toll ticket, and assign to the proper operator to complete the call. All toll boards should be provided with two sets of cords, one set equipped with repeating coils so arranged that they may be inserted in the circuit in addition to the apparatus required in the regular cords. This enables the operator to cut in a repeating coil on a noisy line when necessary. In some cases, the repeating coil is connected to a pair of jacks, but cords with repeating coils are better in many ways. The same cord circuits should be provided with means to enable the operator to listen independently either upon the answering or calling cord, and also to speak and listen across the line without separating the circuits of the calling and answering plugs, and without materially cutting down the transmission between the connected subscribers. In addition to the features mentioned, some cord circuits should be arranged so that even the clearing-out drops may be cut off from the circuit, so as to leave a straight and through connection from line to line without anything in the circuit that may reduce the transmission. Ordinarily 6 cord circuits are sufficient for 8 toll lines. If most of the service is between toll lines and a local central-energy exchange, at least 5 cord circuits should be arranged for a toll-to-central-energy service and 3 cord circuits equipped for toll-to-toll service. No repeating-coil cut-out key need be installed in the toll to local cords, and lamp supervision would be employed on the local side and drop supervision on the toll side of the toll-to-local cords. It is economy and good practice to place the very best operator at the toll boards, as an active and intelligent operator, by saving time, can utilize the lines under her care to the fullest efficiency.

TOLL-TO-TOLL CORD CIRCUIT

18. A cord circuit used for connecting together two toll lines in the Stromberg-Carlson common-battery signaling system is shown in Fig. 6. The toll lines are usually equipped with high wound drops and bridging magneto-telephones. The toll-to-toll cord circuit includes, besides the regular ringing key Rk, a selective ringing key Rt, Rs for use in connection with party-line circuits. There is one such key, called a *master selective ringing key*, for each operator's position. The contacts u, v on all the regular ringing keys at one operator's position are connected at e, i with the two leads running to the master key. With the selective ringing key Rs, Rt in its normal position, the generator is connected across the calling-plug side of the circuit by closing the key Rk. If a party-line circuit, having a telephone instrument connected between each side of a line and the ground, is employed, either telephone may be rung. For, by closing the key Rt, and then Rk, the ringing generator and buzzer are connected between the tip side of the line and the ground, and, therefore, the bell of any telephone instrument connected between the tip side of the line and the ground will ring; and by closing the keys Rs and Rk, the ringing generator and buzzer are connected between the sleeve side of the line and the ground, and any telephone instrument connected between the sleeve side of the line and the ground will be rung. The sounding of the buzzer usually indicates that the line and subscriber's circuit is probably in proper condition.

In connecting together two circuits, one of which is a common or ground return, it is very frequently necessary, in order to avoid noises due to induction or leakage, to have a repeating coil in the cord circuit between the answering and calling plugs; such an arrangement is shown in this figure. The condenser C is connected across the clearing-out drop so as not to impede the flow of the voice current. In this same exchange some of the toll-to-toll cord circuits are not provided with repeating coils. The circuits are



Answering Plug
Tip
Sleeve
Operator's Set
m
w
Lk
Rk
n
v
y
u
Calling Plug
Tip
Sleeve
C.O. Drop
C
S
Night Bell
Repeating Coil
o
t
Buzzer
Gs
Rt
Rs
Gt
Generator

FIG. 6

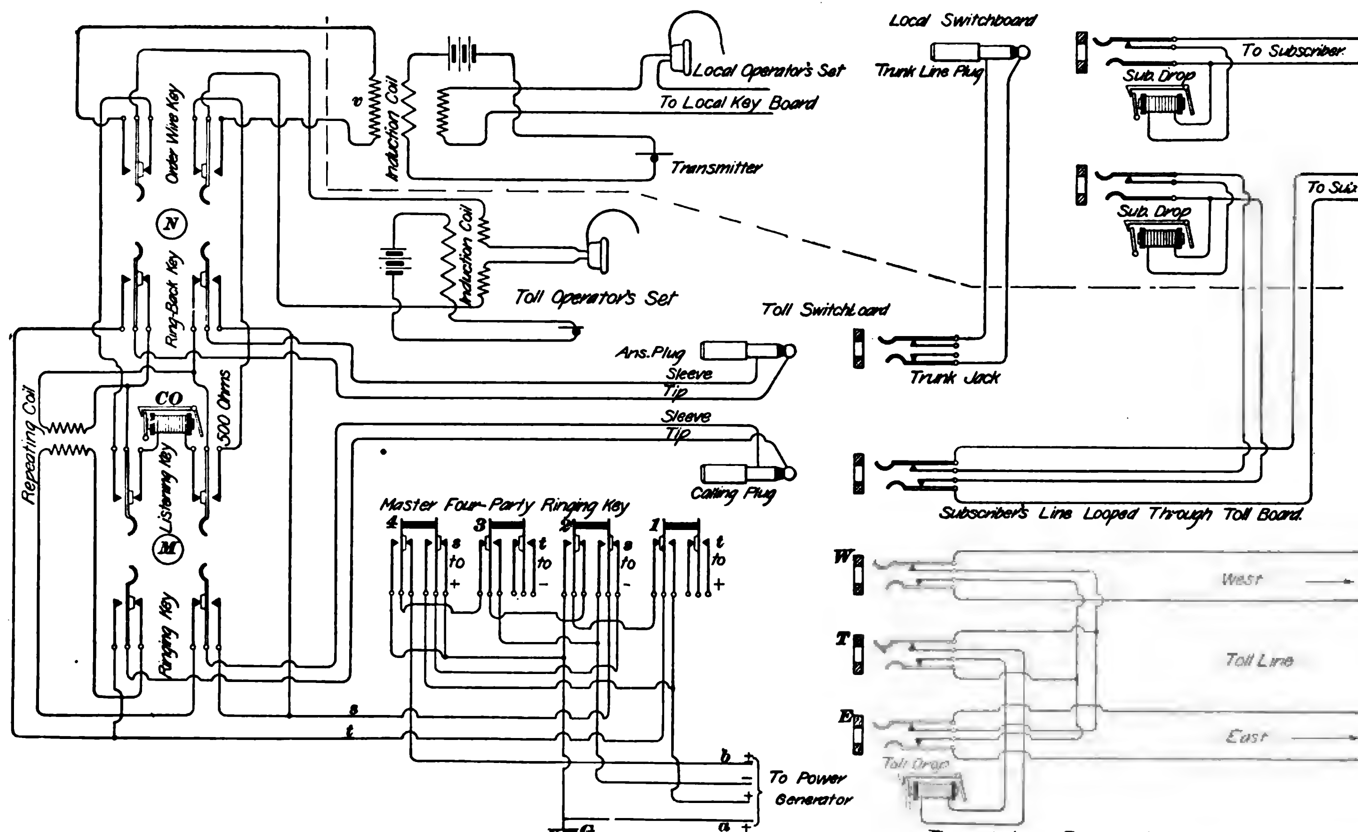
practically the same as shown in this figure, except that the repeating coil is eliminated by connecting *m* directly to *n* and *w* directly to *y* with the high-resistance drop bridged across *m w*. In some of the cord circuits, a double ringing key is employed instead of the selective party-line key *R t*, *R s*. The double ringing key is arranged as shown in Fig. 5, so as to connect the ringing generator across either the calling or the answering side of the circuit.

SMALL TOLL BOARD

19. The circuits of a toll board used in a small town in Indiana, in connection with an ordinary magneto-switchboard to which bridging metallic-circuit lines are connected, are shown in Fig. 7. Only a small portion of the circuits at the local switchboard are shown in the figure.

In order to enable the toll operator to ring any one of four telephones connected to the same line circuit, each operator's position at the toll board is provided with one master four-party ringing key. In the normal position of the buttons of the master key, as shown in the figure, the ringing leads *t*, *s* are connected to a source of ordinary alternating ringing current, that is, to the wires *a*, *b* marked ±. If one of the buttons of the master key is set, *s* will be connected to a source of plus or minus pulsating current and *t* to the ground; or *t* will be connected to a source of plus or minus pulsating current and *s* to the ground, depending on which button is set as indicated at the side of each key. For instance, if key 3 is set, the tip conductor is connected to a source of negative pulsating current, as indicated by *t to* – on the side of the key.

20. Each cord circuit at the toll board is provided with two double-throw keys *M*, *N*. When *M* is closed in the ringing position, the ringing leads *t*, *s* are connected across the calling plug; when closed in the listening position, the toll operator's listening set is connected across the answering plug, and also, through the repeating coil, to the calling plug. The calling and answering sides of the cord circuit



Local Switchboard
Trunk Line Plug
To Subscriber
Sub. Drop
To Sub.
Local Operator's Set
To Local Key Board
Transmitter
Induction Coil
a
Order Wire Key
N
Ring-Back Key
Toll Operator's Set
Toll Switchboard
Ans. Plug
Sleeve
Tip
Trunk Jack
CO
500 Ohms
Repeating Coil
Listening Key
M
Ringing Key
Calling Plug
Subscriber's Line Looped Through Toll Board.
Master Four-Party Ringing Key
s to +
t to −
s to −
t to +
s
t
b
a
To Power Generator
G
W
T
E
West
Toll Line
East
Toll Drop
Three Jacks on Through Toll Line

FIG. 7

are connected together only through the repeating coil; hence a ring-back key is provided, which enables the operator to ring the original calling-subscriber's bell without having to transmit the ringing current through the repeating coil. Pressing the handle *N* so as to close the ring-back key connects the ringing leads *t*, *s* directly across the answering plug, and also cuts off the rest of the cord circuit, including the repeating coil and clearing-out drop *C O*. Pressing the same handle the other way connects the toll operator's talking-and-listening set through an order wire to a third winding *v* on the local operator's induction coil. This coil acts merely as a repeating coil when the toll operator speaks to the local operator. The toll operator's receiver is connected to the middle of the secondary winding of her induction coil.

21. The toll lines that pass through this exchange are connected through three jacks, as shown at *W*, *T*, *E*. By plugging in the east jack *E*, the toll operator's cord circuit is connected to the eastern part of the toll line and the toll drop remains connected to the western part of the toll line. The western end of the line now constitutes a practically separate and independent line. Similarly, by inserting a plug in the west jack *W*, the eastern line to which the toll drop remains connected constitutes a separate line. Inserting the answering plug in the through jack *T* cuts out the toll drop and enables the toll operator to listen on the toll line. Certain subscribers' lines that frequently have to be connected with the toll lines are looped through jacks, as shown in the figure, on the toll board, so that such connections can be made by the toll operator alone.

22. For making connections between toll lines and local subscribers whose lines are not looped through a jack at the toll board, trunk jacks are provided at the toll board to which trunk line plugs at the local board are connected, as shown. In case a connection is to be made from the toll line to a local line having no jack at the toll board, the toll operator after inserting her answering plug in the toll line jack and receiving

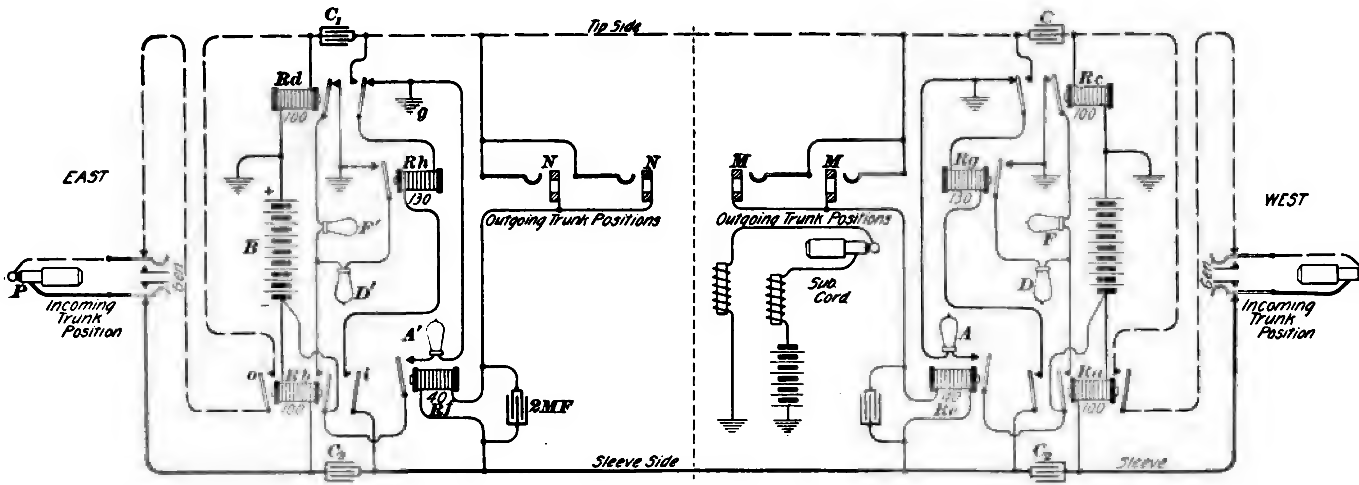
the number of the local subscriber desired, inserts her calling plug in a trunk jack, closes her order-wire key, and orders the local operator to insert a certain trunk plug in the jack of the subscriber wanted; the toll operator rings the subscriber's bell and otherwise supervises the connection. The broken line is used to separate the circuits and apparatus at the local switchboard from those at the toll switchboard.

23. No means of signaling from the local to the toll board was installed; the lack of the same is the most inconvenient feature of the arrangement. However, as only two operators are employed, one at the subscriber and the other at the toll board, it does not cause serious trouble. From local to toll board, it was intended to install a similar circuit to that from the toll to local board, but, as the toll board had to be built and installed on short notice, many such details were neglected. No special busy test is used on the subscribers' lines that are looped through the toll board, but, as a subscriber's line, busy at the toll board, is opened by the insertion of the toll plug, the operator will be notified of this busy condition, if she attempts to call on the busy subscriber's line, by the failure of the relay or buzzer on the pole changer to operate.

A subscriber must first call the local operator and ask for the toll operator, in which case the local operator would speak to the toll operator, who designates the trunk to use. The local switchboard is the ordinary Western Electric magneto, having a capacity of 100 drops. This toll board is used in an exchange where it is required only during the months of August and September, in order to handle a large agricultural crop purchased by traveling buyers who quote prices and give orders by telephone; hence, there is a short period of great activity in the toll business followed by a long, quiet season.

A TWO-WAY TRUNK CIRCUIT

24. The **two-way trunk circuit** shown in Fig. 8 was suggested by James R. Gemmill, in the American Telephone Journal, for use in a central-energy system, where the sleeves



Tip Side
Sleeve Side
EAST
WEST
Incoming Trunk Position
Incoming Trunk Position
Outgoing Trunk Positions
Outgoing Trunk Positions
Sub. Cord
2MF
Sleeve

Fig. 8

of the subscribers' jacks are permanently grounded through high-wound cut-off relays. Since the equipment at each end is the same, an analysis of the apparatus at the east end will serve for the west end as well. The trunk is terminated at each end at jacks as well as with a cord and plug. The jacks *N*, *N* are mounted in the regular outgoing trunk multiple, while the plug *P* is placed at the incoming trunk position. The three lamps F', D', A' are mounted with the plug at the incoming trunk position. Their functions are as follows: F' is the subscriber's signal, and is controlled by the relay *R d*; D' is the operator's signal to indicate when the originating operator has connected the trunk with, or disconnected it from, the calling subscriber; and A' is a supervisory lamp that, when lighted, indicates that the trunk is in use at one of the outgoing-trunk multiple jacks *N*, *N*.

25. The operation is as follows: Suppose that a party at the west exchange is calling a party in the east. The operator at the western station connects her talking set with an order-wire circuit and asks the eastern operator to assign a trunk. As soon as the eastern trunk operator has put the plug *P* in the desired subscriber's jack, a circuit is formed from the battery through the relay *R b*–sleeve of plug *P*–sleeve of subscriber's jack–cut-off relay–ground to battery, energizing the relay *R b* and closing its three contacts. At the same time, the calling operator puts a cord in the jack *M*. The subscribers' cords, it should be stated, have battery on the sleeve and ground on the tip. A circuit is now formed from the battery on the sleeve of the subscriber's cord at the western station through sleeve of jack *M*–relay *R e*–sleeve side of trunk–contact *i* of relay *R b*–winding of relay *R h* to ground *g*. The relay *R e* at the western station being energized, closes the circuit of the supervisory lamp *A*, indicating to the incoming operator at the western station, who also assigns the trunks to be used in one direction, that the trunk is being used in the reverse direction. The relay *R h* in the eastern station, being energized, opens the ground connection of the operator's signal lamp D', indicating

to her that the western operator has put up the correct trunk. As soon as the called party in the east answers, a circuit is formed from the battery through the winding of relay *R b*–subscriber's line–contact *o* winding of relay *R d*–ground. This energizes the relay *R d* and opens its two contacts, putting out the subscriber's signal lamp *F'* and transferring the grounded connection of relay winding *R h* from *g* through the tip side of the trunk to the tip side of the subscriber's cord, whose plug is now inserted in jack *M*, which causes the armature of the relay *R h* to be still attracted and so keep open the circuit of the operator's signal lamp *D'*. *A* is the only lamp now lighted.

When the eastern subscriber hangs up his receiver, the circuit through the relay *R d* is opened, its armature is released, and the subscriber's disconnection signal is given by the lighting of the lamp *F'*, the relay *R b* still receiving enough current to hold its armature. When the calling party in the west hangs up his receiver and the operator at that end removes the subscriber's plug from jack *M*, the battery circuit at the sleeve of the jack *M* is opened and the relays *R e* and *R h* release their armatures, thereby putting out lamp *A* and lighting the lamp *D'*, which is a signal for the east operator to take down plug *P*, thereby restoring the trunk to its normal condition. The reverse operation takes place when the calling party is in the east and the called party in the west. The condensers bridging the relays *R e* and *R f* reduce the retardation of those relays to the voice currents, while the condensers C, C_1, C_2, C_3 separate the different signal circuits so that the signals may be operated independently of each other.

26. Advantages of a Two-Way Trunk Circuit.—The best practice of modern telephone engineering is to so distribute the trunking facilities that a maximum efficiency is attained. In the offices where the number of messages requiring trunk service does not keep the trunks busy 50 per cent. of the time, which we will say is 24 hours, the cost of regular incoming and outgoing trunks in maintenance and construction is out of proportion to their earning capacity.

A two-way trunk, in exchanges of moderate size, is thoroughly practical and, being equivalent to one incoming and one outgoing trunk circuit, does the work of two such one-way trunk circuits.

TWO-WAY ORDER-WIRE CIRCUIT

27. Between main and branch exchanges, it is quite customary to have both incoming and outgoing order-wire circuits, requiring two pair of wires. Where the branches are some distance from the main exchange, or where cable or cross-arm capacity is at a premium and there is not enough business to keep at least two one-way order wires busy, a circuit by which one pair of wires can be used both as an incoming and outgoing order wire becomes desirable. Such a circuit, designed by William Geckler to meet this requirement and described in the American Telephone Journal, is shown in Fig. 9. In this case, the main exchange was of the central-energy type

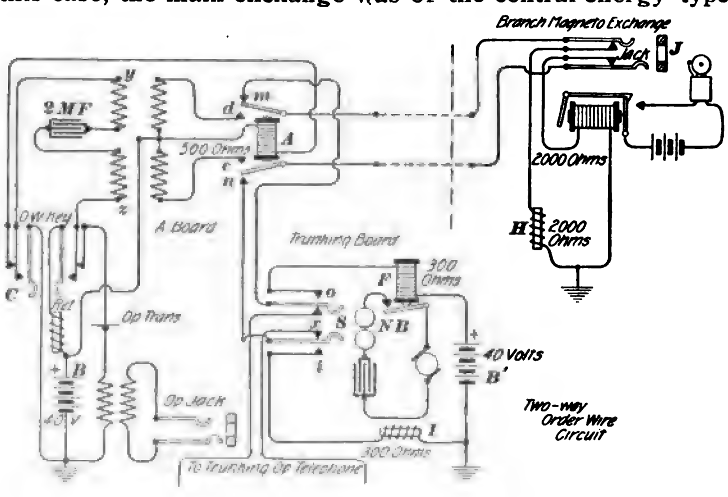


FIG. 9

and the branch exchanges were of the magneto-types. At the magneto-exchange, only a slight alteration was required in a subscriber's line equipment to make it serviceable for terminating the order-wire circuit; the necessity of equipping the branch exchanges with order-wire keys was thus avoided.

The regular drop was exchanged for one having a resistance of about 2,000 ohms, and in series with it was inserted an impedance coil of like resistance. An earth connection between the drop and impedance coil was made as indicated in the figure.

28. Normally, the circuit stands closed from the branch-exchange jack over the line wire through contacts *m*, *n* on relay *A* and inner contacts *x* on shifting key *S* to the trunking operator's telephone.

The *A* operator at the main exchange, on closing the order-wire key *C*, causes her telephone set to be connected with the primary winding *y z* of the repeating coil and at the same time closes the battery circuit through the winding of the relay *A*. This closes the circuit from the positive side of battery *B* through the contacts *d*, *e* over both wires to the branch exchange through drop *D* and impedance coil *H* in multiple to earth which causes the drop at the branch exchange to release its shutter. This informs the branch operator of a call. It is answered in the regular manner by inserting the plug of an answering cord into the jack *J*.

The shifting key *S* on the trunking board is employed to cut in a night-alarm circuit. If this key is thrown to the outer contacts *i*, *o*, the insertion of a plug into jack *J* at the branch switchboard allows current to flow from the positive side of battery B' through relay *F*–contact *o*–contact *m*–one side of order-wire circuit–tip spring of jack *J*–operator's telephone set at branch exchange–sleeve spring of jack *J*–other side of order-wire circuit–contact *n*–contact *i*–impedance coil *I* to negative side of battery, thereby closing relay *F* and ringing the night bell *NB*. The trunking operator returns key *S* to normal position to answer the call.

Care must be exercised in connecting the battery for the night alarm so that positive battery will be in connection with that side of the order-wire circuit which passes through the impedance at the branch exchange to ground. If connected in the reverse manner, the shutter on the drop *D* at the branch exchange will be released each time the key *S* is set for the night alarm.

29. Chief-Operator's Desk.—In large exchanges, there is usually a chief operator, who has direct charge of all the operators. She is provided with a desk that should be equipped with every facility to enable her to watch the operators and observe the service. In addition to the usual listening taps that run from across the operators' telephone sets to the chief-operator's desk, and pilot-line and pilot-supervisory lamps, the chief-operator's desk should be provided with two or three observing signals, to which any line in the exchange can be bridged and its service kept under her personal observation for a stated period. Attention lamps between the desk and the operators' positions with the necessary call wires, whereby the chief operator can signify her intention to speak to all or any of the operators, and also private lines to the wire chief, manager's desk, etc. are very useful.

A tap bell on the switchboard and a call bell in the operators' quarters for use in summoning and retiring relief operators, and controlled from buttons placed on the chief-operator's desk, is also a very useful feature that is generally omitted from the chief-operator's equipment.

30. A **holding coil** is used principally in connection with lines from the wire chief's, or manager's, desk to the switchboard, the object being to provide an arrangement whereby the party at the desk may be able, while having a connection on one line, to take up a new connection and at the same time hold the previous connection as long as desired. If it were not for the holding coil, the supervisory signal at the switchboard would be displayed and the connection taken down when the desk operator disconnected from a line. The means by which this result is avoided is shown in the diagram, Fig. 10. The lines from the switchboard to the desk are terminated at double-throw keys, so that moving a key in one direction connects the desk operator's set to the line, while moving the key in the reverse direction bridges a 600-ohm retardation coil (the holding coil) across the line to the switchboard, thereby preventing the operation of the

supervisory signal and holding the connection until the desk operator is at liberty to take it up again. The diagram also shows a common method of wiring such circuits.

A ringing current from the switchboard will operate the self-restoring drop and line signal, to which the desk opera-

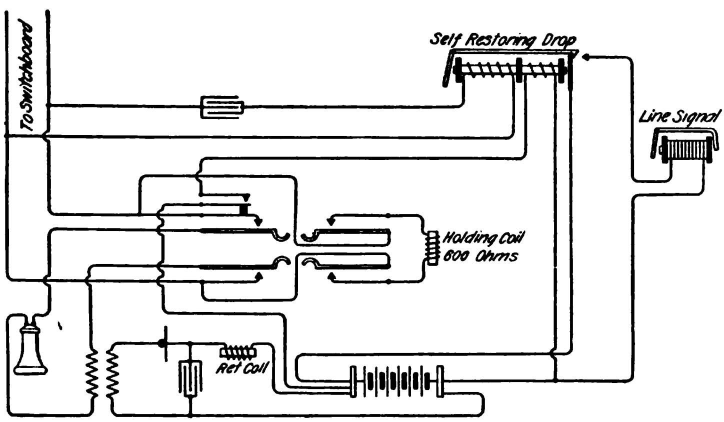


Fig. 10

tor responds by throwing the double-throw key to the left, thereby connecting the desk telephone set across the switchboard circuit and also, by connecting the restoring coil of the drop across the battery, restores the shutter of the drop and also the line signal.

SWITCHES ON TOLL LINES

31. On long toll lines passing through intermediate telephone stations, it is best to have some kind of a switching device by means of which the toll line can be used, opened, and tested both ways from such stations. A simple arrangement for use on bridging toll lines consists in placing three small knife switches (called *baby knife switches*) in a waterproof box on the pole nearest the intermediate telephone station, the switches being connected as shown in Fig. 11. Should only the switch *E* be opened, the intermediate station or house telephone *H* is connected only to the west line, and

vice versa; opening the switch *I* cuts the house telephone off both lines.

A little different arrangement is shown in Fig. 12, requiring one baby knife switch *C*, and a double-throw knife switch *T*. By the use of the latter, the house telephone *H*

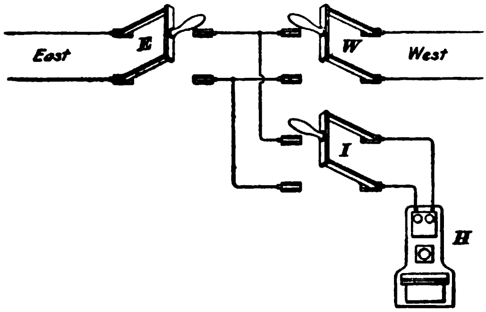


FIG. 11

can be connected to either the east or west line if the switch *C* is open. Ordinarily, both switches would be closed, thus bridging the telephone across the line extending in both directions.

With either of these arrangements, the person in charge of the intermediate station can be instructed, when trouble occurs on the line, to determine with the switches which

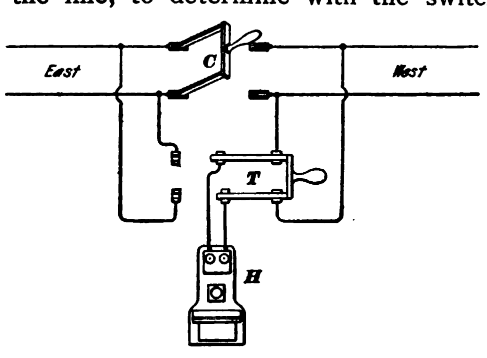


FIG. 12

portion of the line is in trouble and to report to headquarters at one end or the other. The box containing the switches on the pole should be placed out of reach of meddlesome

persons, be water-tight, and so shallow that the door cannot be closed while the switches are open. All connections with the switches should be made with good rubber-covered wire and should preferably be soldered. By means of a number of such stations on a long toll line, tests can be made from station to station until the trouble is located between two of them.

BELL CENTRAL-ENERGY SYSTEM

(PART 1)

REPEATING-COIL MULTIPLE-SWITCH-BOARD SYSTEM

SUBSCRIBER'S INSTRUMENT

1. The central-energy system used by the licensees of the American Bell Telephone Company employs the Hayes principle of utilizing one battery for all circuits and a repeating coil in each cord circuit. As the principles of the various systems have been explained in preceding Sections, the description of the **Bell central-energy system** will begin with the subscriber's telephone, show the changes made in the design, and give the reasons for making them. It has already been explained that a 5,000-ohm bell may be used in a subscriber's telephone when the bell is bridged permanently across the line circuit. A similar arrangement was introduced on a large scale in Philadelphia, but "to make assurance doubly sure" the bells were wound to a resistance of 6,000 ohms. While the system was successful as far as the operation of the signals was concerned, it was found that the bridging of a great number of telephones across the lines, even when the resistance of each bell circuit was 6,000 ohms, caused such a large consumption of current that the system was too costly for commercial use. To overcome this defect, a new type of subscriber's telephone was devised, which in addition to avoiding the defect already mentioned contained other superior features.

CONVERSATION CIRCUIT

2. Repeating Coil.—Fig. 1 shows two subscribers' telephones connected to the common battery *B*; all exchange apparatus, except what is actually in the circuit connecting the two lines while a conversation is being held, is omitted.

A repeating coil with four windings is represented; each winding contains 40 ohms and 2,000 turns. The repeating coil is wound in various ways on a core of soft-iron wire, so arranged as to form a practically closed, or complete, magnetic circuit. This repeating coil is sometimes constructed as follows, although the above-mentioned winding is that generally given: The iron core is $\frac{1}{2}$ inch in diameter by 6 inches long; the two pieces of insulating material forming the spool ends are $\frac{1}{4}$ inch thick and the center one $\frac{1}{8}$ inch thick. The two winding spaces are about $2\frac{11}{16}$ inches long, each space containing room for two windings. Each winding has sixteen layers of No. 26 single silk-covered wire; each inner winding has a resistance of about 20 ohms and each outer winding about 34 ohms. One inner and the opposite outer winding, having a resistance of about 54 ohms (about 4,700 turns), form one half of one spool; the remaining two windings form the other half of the same spool. Two such spools on the same iron core form the complete repeating coil for one circuit. Information concerning the connection and winding of these repeating coils and the low resistance required between them and the battery terminals was given when the principle of the Hayes system was explained.

3. Connected in the cord circuit are two supervisory relays *A R*, *C R* shunted by non-inductive resistances *A r*, *C r*; the non-inductive resistance is usually wound over the relay coil. A Bell engineer states that the relay coil has a resistance of 10 ohms and is shunted by a non-inductive resistance of 100 ohms. Others state that the relay coil is 20 ohms and the shunt 30 ohms. The non-inductive shunts offer much less opposition to the voice currents than the relay

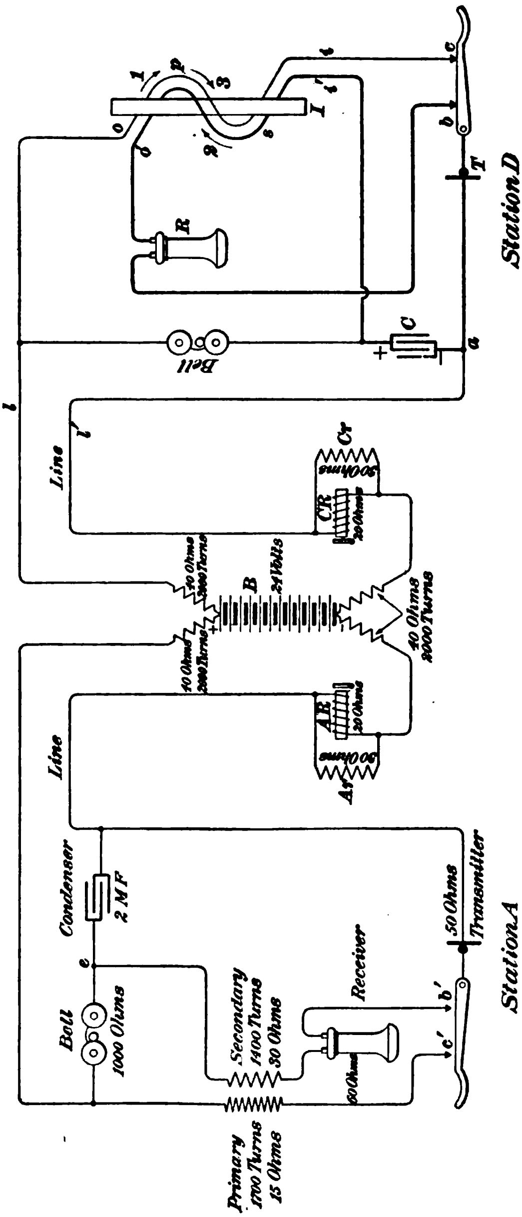

Station D
Station A
Line
Line
Bell
Bell
1000 Ohms
Condenser
2 M F
Secondary
1400 Turns
30 Ohms
Primary
1100 Turns
15 Ohms
Receiver
50 Ohms
Transmitter
B
24 Volts
40 Ohms
2000 Turns
CR
AR
Cr
Ar

FIG. 1

windings. However, the shunt is of sufficiently high resist-ance to compel enough of the battery current to flow through the relay coil to operate it.

At station *A*, the subscriber's circuits are shown in a customary and convenient way; while at station *D*, the same circuits are arranged to facilitate an explanation of the theoretical action of the instrument. The subscriber's instrument consists of a 1,000-ohm polarized bell of the type used in a local-battery instrument, in series with a condenser of 2 microfarads capacity, and the two are permanently bridged across the line. When the receiver rests on the hook, the receiver and transmitter circuits are open at the hook-switch contacts. When the receiver is removed from the hook, the primary winding of an induction coil and the transmitter are connected across the two line wires; and this same primary winding, the receiver, the secondary winding of the induction coil, and a condenser form another circuit across the line wires. It will be noticed that, among the changes, the induction coil has again come into use. The presence of the condenser keeps the line open as far as the battery current is concerned when the receiver is on the hook, so that no consumption of current can take place through the instrument, while it offers an easy path for the alternating current used to ring the subscriber's bell. The resistance of the transmitter is made much higher than that of the local-battery instrument in order to get a sufficient degree of sensitiveness with the line in series; under normal conditions it is about 50 ohms.

4. Induction-Coil Windings.—A Bell engineer states that the resistance of the primary coil *p* is about 8 ohms, while that of the secondary *s* is in the neighborhood of 50 ohms. These coils are wound in various ways. The induction coil is most frequently stated to have a primary wound with about 1,700 turns to a resistance of 15 to 17 ohms and the secondary with 1,400 turns to a resistance of 25 to 30 ohms. The core of this coil is $\frac{1}{4}$ inch in diameter, 3 inches long, and composed of No. 26 Norway-iron wire.

Another induction coil used for the same purpose, and which is said to give very superior service, has the following dimensions: diameter of core, ½ inch, composed of No. 24 annealed Norway-iron wire; length of core, 4 inches; length of winding space, 3½ inches; depth of winding space, $\frac{5}{16}$ inch; primary winding, 1,550 turns, No. 27 single cotton-covered wire, 15 ohms; secondary winding, 1,550 turns, No. 29 single cotton-covered wire, 30 ohms.

Still another way to wind the induction coil is as follows: The secondary is wound next to the iron-wire core and the primary over it. The primary is wound with 2,600 turns of No. 24 B. & S. to a resistance of 15 ohms, and the secondary with 1,300 turns of No. 33 wire to a resistance of 30 ohms.

5. The ends marked *i*, *i'* are the inside and those marked *o*, *o'* the outside, the two coils being wound in the same direction, as indicated. When the transmitter is at rest, it will have a fixed resistance and current flows from the positive terminal of the battery through *l–o–p–i–c–T–a–l'*– negative terminal of *B*; arrow *1* indicates the direction of this current through *p*. The number of turns in *p* and the normal current strength should be about such that the iron core *I* is magnetized to a point where it is most sensitive to the slightest change in the current in either *s* or *p*. That is, a given change in the strength of the current should produce a greater change in the magnetism of the core than would be the case were it magnetized to a much less or much greater degree.

6. Operation.—The following explanation of the action of the subscriber's instrument only is based on one given in the American Telephone Journal, by Mr. W. W. Dean. The difference of potential between the points *a* and *c* will be equal to the current times the transmitter resistance. The condenser *C*, being connected from *a* through *s* and *R* to *b* will be charged to the potential that exists between *a* and *b*, the + and – signs on the figure indicating the polarity of the charge. Suppose that the resistance of the transmitter is

suddenly lowered by speaking into it. The difference of potential between *a* and *b* will suddenly be reduced, because the current will not be proportionally increased in strength; and this potential, being lower than that of the condenser, will cause the latter to discharge some of its electricity through *i′–s–o′–R–b–T–a*, the direction of this discharge current through the secondary *s* being shown by the arrow *2*. This current will induce a current in the primary *p* in the opposite direction—that is, in the direction of arrow *3*. Since *p* has more turns than *s*, this current *3* will be of higher potential than the inducing current; and being in the same direction as the battery current *1*, which is also increasing in strength because the transmitter is decreasing in resistance, will cause a considerable increase in the current in the line circuit. When the transmitter increases in resistance, the potential between *a* and *b* rises and current flows into the condenser from *b* through *R–o′–s–i′*; that is, through the secondary in the opposite direction to the arrow *2*. This induces a current in the primary *p* in the opposite direction to the arrow *3*. The battery current through *p* at the same time decreases in strength because of the increase in the transmitter resistance, while the induced current in *p* will still further reduce the strength of the current in the line circuit. Thus, the changes in current strength in the line are much greater than would be the case were no induction coil used. This can be proved by reversing the primary coil in the circuit, which will cut down the loudness about one-half.

The fluctuating current produced by talking into the transmitter at station *A* flows through *l–o–p–i–c–T–a–l′*. This induces in *s* a current that flows through *o′–R–b–T–a–C–i′*, the condenser offering little opposition to this very rapid alternating current. Or, it may be considered that the alternating potential induced in *s* causes the condenser to be charged alternately in opposite directions, or the normal charge on the condenser to be varied in amount; in either case, the charges flow in and out of the condenser and produce the desired effect on the receiver *R*.

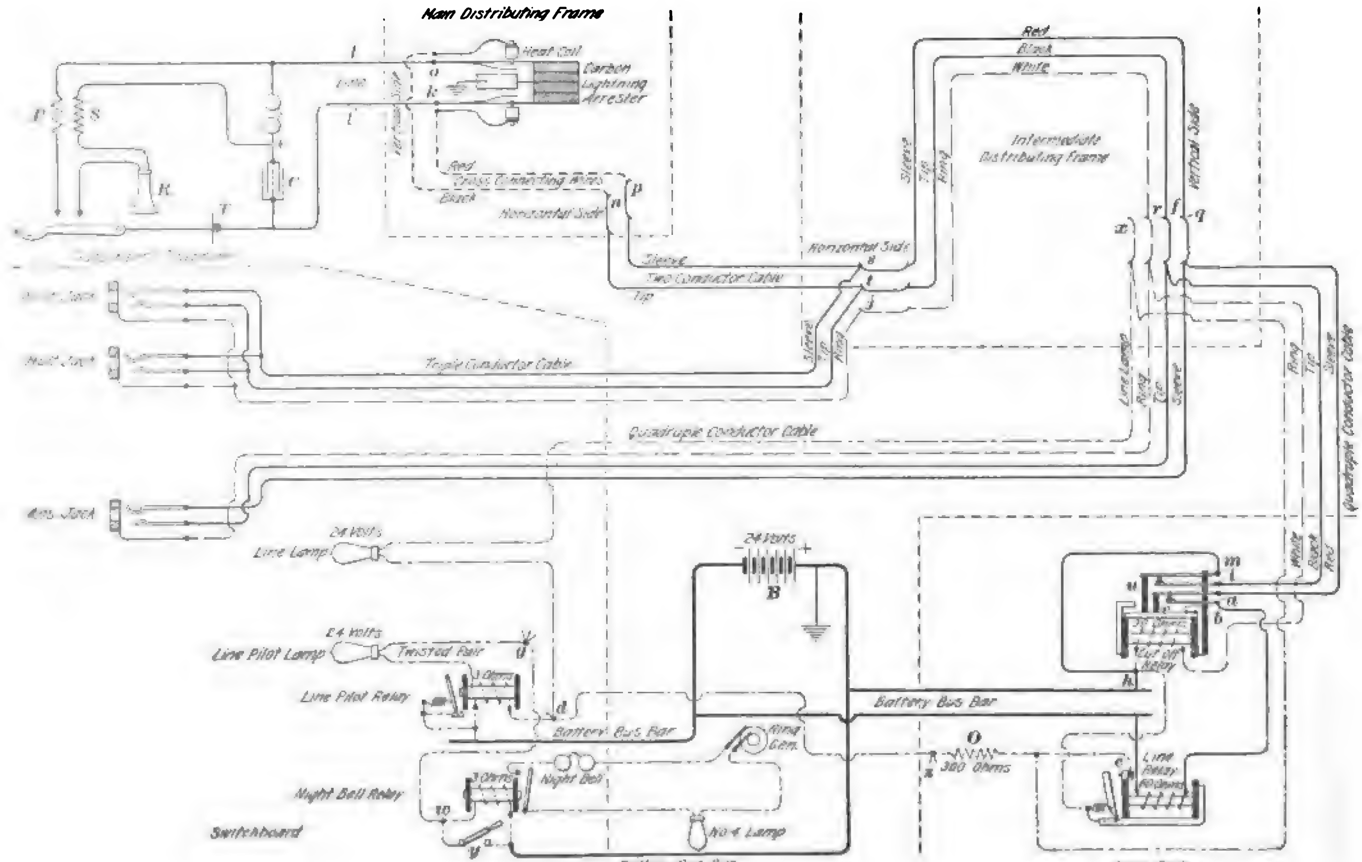
LINE CIRCUIT

7. In Fig. 2 is shown one complete line circuit, including the arrangement of the main frame, intermediate distributing frame, relay rack, switchboard apparatus, and connecting cables.

The lines are first brought to the vertical side *o*, *k* of a main distributing frame, where the lightning and sneak-current arresters are mounted. After connection with these, the circuit is continued through jumper wires (rubber-covered connecting wires twisted in pairs) to the horizontal side *n*, *p* of the main distributing frame. From there, they are carried in cables to the horizontal side *s*, *t* of an intermediate distributing frame, where a third wire *j* is started. From there, three wires for each line are carried, in cables, to the multiple jacks on the switchboard. Three branch wires are carried from the same points on the horizontal side, by jumper wires, to the vertical side, *q*, *f*, *r*, where a fourth wire *x* is started. From there, the four wires are carried to the answering jacks and line lamps through one cable and to the relay rack through another cable.

When the cut-off relay is energized, the iron armature that is pivoted at the rear end is drawn up, thereby causing the insulating pieces *u*, *v* to raise the springs *a*, *m* out of contact with the springs *b*, *i*. All armatures, except that of the night-bell relay, are restored, by gravity, to their normal position when the relays are deenergized. As there is only one night-bell relay for the whole switchboard, an ordinary Morse pony relay of about 3 ohms resistance is used.

8. Use of Main and Intermediate Frames.—When a subscriber moves, his new line can be readily connected at the main distributing frame by means of cross-connecting wires to the lugs *n*, *p*, and hence to the same switchboard circuit as before; therefore, his line number on the switchboard and in the subscribers' directory does not have to be changed. By means of the jumper wires at the intermediate distributing frame, the jacks and line lamps of busy


Main Distributing Frame
Heat Coil
Carbon
Lightning
Arrester
Line
Vertical Side
Red
Cross Connecting Wires
Black
Horizontal Side
Sleeve
Two Conductor Cable
Tip
Horizontal Side
Tip
Ring
Intermediate
Distributing Frame
Vertical Side
Red
Black
White
Triple Conductor Cable
Line Lamp
Quadruple Conductor Cable
Quadruple Conductor Cable
Ans. Jack
24 Volts
Line Lamp
24 Volts
Line Pilot Lamp
Twisted Pair
Line Pilot Relay
Battery Bus Bar
24 Volts
Ring Gen.
Night Bell Relay
Night Bell
No 4 Lamp
Switchboard
Battery Bus Bar
Battery Bus Bar
300 Ohms
Cut off Relay
Line Relay
Relay Rack
Fig. 2

telephones can be evenly distributed among all the operators without interfering with the multiple jacks or changing the line number of any subscriber. The number of the answering jack and line lamp does not have to be the same as that of the line, although its number can be changed to agree with the line number. For instance, by disconnecting the three jumper wires at r, f, q and connecting them to another set of similar lugs, the same line and multiple jacks may be connected to another answering jack and line lamp at any other operator's position on the whole switchboard. The corresponding line and cut-off relays are generally associated with the same answering jack and line lamp. There is only one conductor d–z from each operator's position to the relay rack; hence, these wires may all be run in one separate cable. Wires with different-colored insulation are used for different circuits and care should be taken to always use the same color for the same connection, otherwise the confusion that will arise from the indiscriminate use of different colors will cause a great amount of delay and annoyance in tracing circuits.

9. Operation of Line Circuit.—Normally, the subscriber's receiver R rests on the hook switch, the condenser and bell, which are in series, form the only circuit in the subscriber's instrument between the two line wires l, l', and the 24-volt storage battery B at the central office is connected across the line wires in the circuit a–b–line relay–B–h–m–i.

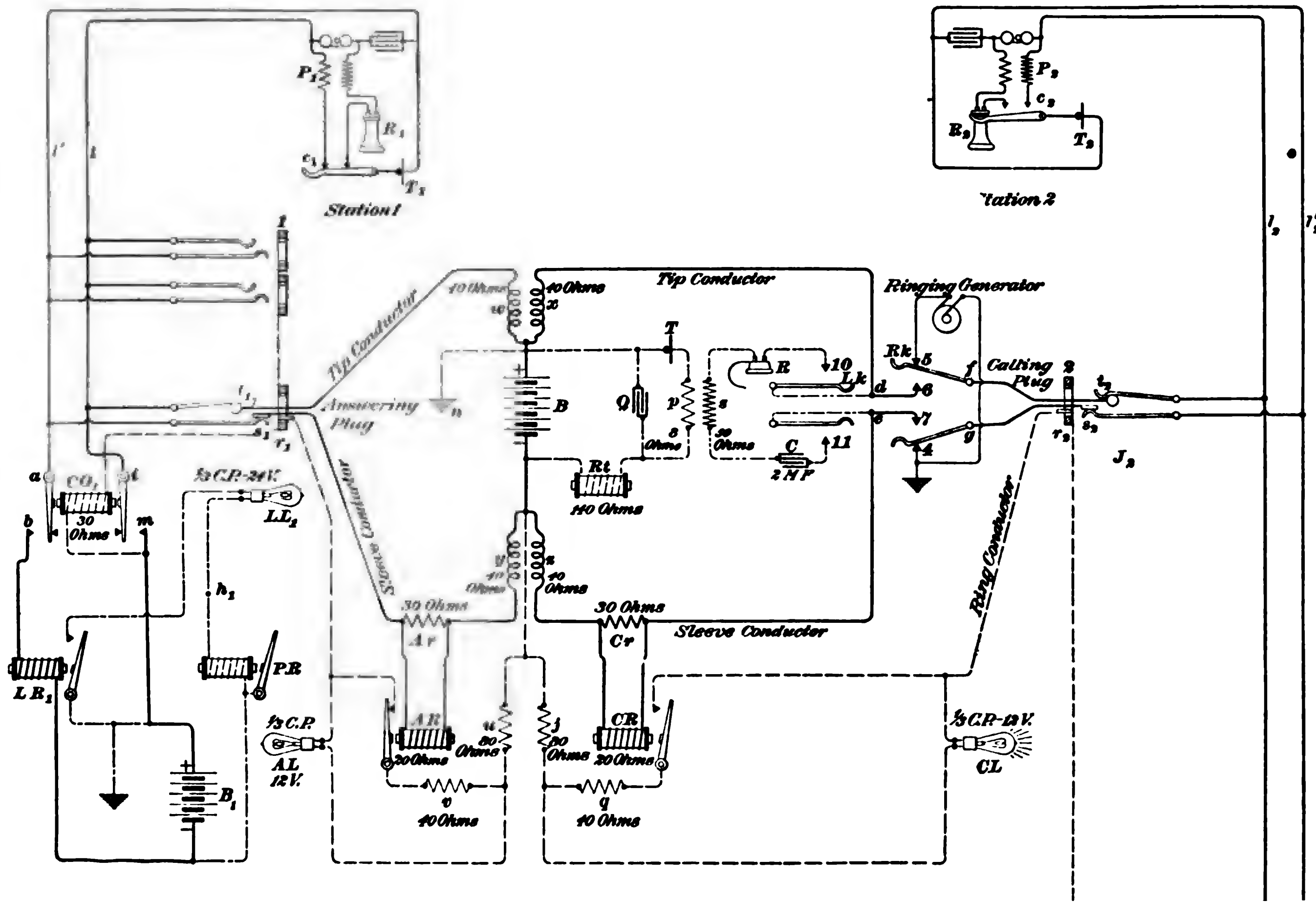
When the subscriber removes the receiver R from the hook, the transmitter T and primary winding P form a circuit of sufficiently low resistance to allow enough battery current to flow from $+B$ through h–m–i–f–t–n–heat coil on one side of arrester frame–o–l–P–T–l'–k–heat coil on the other side of arrester frame–p–s–q–a–b–line relay to $-B$, to cause the line relay to attract its armature and close contact c. This allows current to flow from $+B$ through h–armature of line relay–c–$\left\{\begin{matrix} x\text{–line lamp–}d \\ O\text{–}d \end{matrix}\right\}$–line-pilot relay to $-B$. The 24-volt, $\frac{1}{3}$-candlepower line lamp and resistance O are in parallel, but the line lamp will receive enough current to light

it, thereby notifying the operator that her attention is desired on that line. The 300-ohm resistance *O* is used as a shunt to the line lamp, so that, if the line lamp burns out, the subscriber can still call up the office through the line-pilot relay. Hence, if the line-pilot relay lights when no line lamp lights, the operator knows that some lamp is in trouble.

The faulty lamp may be located by plugging successively into all answering jacks at that operator's position with a plug having the tip and sleeve short-circuited and the ring open. This will cause only the good line lamps to light; the failure of one to light will locate the faulty lamp. This is not, however, the main purpose of the line-pilot lamp. It is to enable the supervising operator to observe how the operator is attending to her work. The resistance *O* is no longer considered necessary and is even being removed from many switchboards in which it was originally installed.

10. There is one line relay and line lamp for each line circuit, but only one line-pilot relay and one line-pilot lamp for each operator's position, on the face of the board. The line-pilot-lamp circuits for the whole switchboard are connected together at some point *g* and pass as one circuit through the night-bell relay. This relay is short-circuited by the switch *y*, except at night, or such other times, when so few calls are being received that one or only a few operators can easily attend to the entire switchboard. When the night-bell relay closes, the regular exchange ringing generator is connected through the No. *4* lamp, which has a suitable resistance, to an ordinary 1000-ohm bell. The night bell gives an alarm when a call is made, the lighted line-pilot lamp shows the operator's position to which the line comes, and the lighted line lamp there indicates the line.

The line relay should not operate and should release on a resistance of 10,000 ohms or more, but it should operate on any line resistance up to and including 750 ohms. To test a line relay, short-circuit it and gradually increase the resistance. The relay should not release its armature until the resistance has been increased to about 10,000 ohms.


Station 1
Station 2
Tip Conductor
Sleeve Conductor
Ring Conductor
Answering Plug
Calling Plug
Ringing Generator
40 Ohms
30 Ohms
140 Ohms
20 Ohms
80 Ohms
10 Ohms
2 M F
½ C.P.-24 V.
½ C.P.-12 V.
½ C.P. AL 12 V.
CO1
LR1
PR
LL1
AR
CR
CL
Rt
Rk
Lk

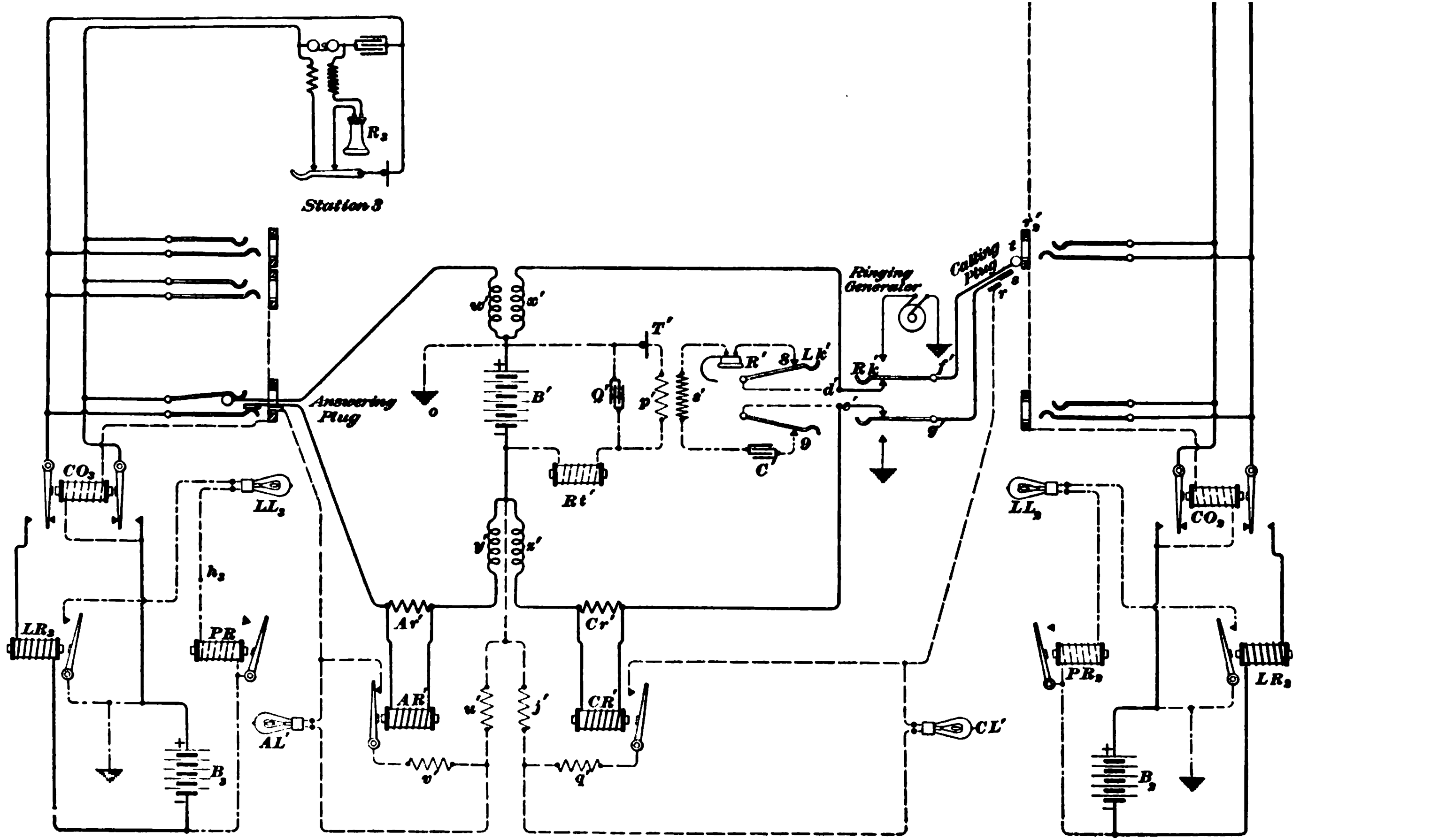

Station 3
Answering Plug
Calling Plug
Ringing Generator
CO3
LL3
LR3
PR
B3
AL'
AR'
Ar'
CR'
Cr'
CL'
LL2
CO2
PR2
LR2
B2
B'
Q'
T'
Rt'
R'
Lk'
Rk'
C'
R3
h3

FIG. 8

§ 20

CORD CIRCUIT

11. Two operators' cord circuits and three subscribers' line circuits are shown in Fig. 3. In each cord circuit, there is one repeating coil having four windings w, x, y, z; in the answering side of the circuit, there is one supervisory relay AR controlling the answering supervisory lamp AL; and in the calling side, one supervisory relay CR, controlling the calling supervisory lamp CL. As these two relay coils are directly in the talking circuit, they are shunted by a non-inductive resistance, which is sufficiently high, however, not to interfere with the operation of the relay by the battery current, the relay coil having a sufficiently low resistance.

The resistance u (80 ohms) plus that of the cut-off relay CO, (30 ohms) associated with the line is about equal to the hot resistance of the lamp AL, and hence with the two in series across 24 volts, the lamp must light with 12 volts across its terminals. When, however, the 40-ohm coil v is connected by the supervisory relay AR in parallel with the lamp AL, the 40-ohm coil takes such a large portion of the current flowing through u that the lamp goes out.

12. Two styles of lamps have been adopted for this system, one to work on 24 volts and the other to work on 12 volts. To the first style belong the line lamps, and to the other the supervisory lamps. Since a supervisory lamp has a resistance of 110 ohms, a resistance of 80 ohms, in addition to the 30 ohms in the cut-off relay, must be placed in series with it to reduce the effective pressure on the lamp to 12 volts. Two resistances q, v of 40 ohms each are placed in each shunt circuit, so that the supervisory lamp will be sufficiently dimmed, while the current will not be increased enough to injure either the cut-off relays or the coils u, j. With the shunt circuit open, the total resistance in one supervisory lamp circuit is $110 + 80 + 30 = 220$ ohms and the current flowing is therefore $\frac{24}{220} = .11$. If the lamp were shunted out by a short circuit, the current in this circuit would be about .22 ampere, which would overheat the 80-ohm

resistance and the cut-off relay and probably burn out one or both of them. When, however, the lamp is shunted through a 40-ohm resistance, the total resistance of the circuit is about 140 ohms and the current flowing is .16 ampere, which is not too high for the apparatus. The amount of resistance necessary to be placed in this shunt circuit around the lamp has been determined by trial. It was first supposed, as a result of calculation, that 60 ohms would be sufficient to make the lamp dim enough to prevent the operator from observing it. It was found, however, that this resistance was so high that in the majority of cases the lamps would retain sufficient brilliancy to confuse the operator. After several trials, a 40-ohm resistance was found to meet the requirements of the case.

13. The repeating coils are mounted on a rack and wired to a connecting board on the rear of the operator's position. The resistance coils u, j, v, and q are wound on one spool and mounted above the supervisory relays in the rear of the operator's position. The supervisory lamps are mounted in the horizontal plug shelf in front of the plugs with which they are associated. About .1 ampere is required to properly light a supervisory or line lamp. There are usually fifteen such cord circuits for each operator's position, or forty-five to a section. The plugs have three contacts, the tip t, sleeve s, and ring, or shank, r; they make contact with corresponding parts of the jacks.

OPERATOR'S TELEPHONE CIRCUIT

14. The listening key is normally open, but will remain either open or closed. A 2-microfarad condenser C in the operator's listening circuit prevents the battery current from flowing through the operator's receiver when the listening key is closed. The retardation coil $R\,t$, having a resistance sometimes of 100 ohms, and sometimes of 140 ohms, not only limits the current in any one transmitter circuit, but also enables current to be supplied to all the operators' transmitters from one battery without producing the cross-talk and

interference that would otherwise result, between the various operators' circuits, because with this arrangement the very rapid fluctuations in current caused by the transmitter are practically confined to the circuit Q–T–p. The condenser Q of 2 microfarads capacity improves the transmitting qualities by being charged and discharged through the primary winding p, which has a resistance of 8 ohms and 1,000 turns, in much the same manner as already explained in connection with the subscriber's telephone.

OPERATION OF CORD CIRCUIT

15. Assume all circuits to be in their normal position and that subscriber *1* has just lifted the receiver off the hook in order to call for subscriber *2*. For convenience, several batteries and ringing generators are shown, but there is only one battery and one ringing generator. Normally, no current flows through the cut-off relay $C\,O_1$, and consequently a rests against b and i rests against m. The removal of receiver R_1 from the hook connects the transmitter T_1 and one winding P_1 of the induction coil across the two line wires, thus allowing sufficient current to flow from $+B_1$ through the circuit m–i–l–P_1–c_1–T_1–l'–a–b–$L\,R_1$ to $-B_1$ to close the line relay $L\,R_1$ and cause the line lamp $L\,L_1$ and the line-pilot lamp, which is not shown in this figure, to light. The operator then inserts an answering plug, usually the rear plug, into the answering jack belonging to line *1*, which is located on the switchboard immediately above the line lamp $L\,L_1$. This produces two results: a current flows from $+B$ through w–t_1–l–P_1–c_1–T_1–l'–s_1–$\left\{\begin{matrix} A\,R \\ A\,r \end{matrix}\right\}$–$y$ to $-B$. Enough of this current flows through the answering supervisory relay $A\,R$ to close it, thereby shunting the answering supervisory lamp $A\,L$ by the resistance v, which prevents the lamp $A\,L$ from lighting. Current for the subscriber's transmitter now comes through the repeating coil and the cord circuit. Current also flows from $+B$ through n–ground–$C\,O_1$–r_1–$\left\{\begin{matrix} A\,L \\ v \end{matrix}\right\}$–$u$ to $-B$ and

closes the line cut-off relay CO_1, thereby breaking the circuit at b through the line relay LR_1, which, in turn, causes the line lamp LL_1 to go out, the line-pilot relay PR to release its armature and also the line-pilot lamp to go out. The operator closes her listening key Lk, thereby bridging her receiver circuit R–s–C across the tip and sleeve conductors, which enables her to converse with the subscriber. Variations in current strength through the winding p of the operator's induction coil induce an electromotive force of variable intensity in the secondary winding s, which has a resistance of 50 ohms and 2,000 turns, thereby causing a fluctuating current to flow in and out of the condenser C through the circuit s–R–10 (the listening key Lk is now supposed to be closed as shown at Lk') –d–x–B–z–C r–e–11. This fluctuating current induces, through the repeating coil $w\,x\,y\,z$, a similar current in the subscriber's circuit, thereby affecting the receiver R_1. In a very similar manner, fluctuating voice currents, due to the subscriber talking into his transmitter, are repeated in the operator's receiver circuit. The non-inductive shunts across the supervisory relays allow the voice currents to flow readily through either sleeve conductor.

16. Suppose that subscriber 2 is wanted, that the usual busy test, which is explained later, has been made and the line found to be not busy, and that the operator has therefore inserted the calling plug into a multiple jack of line 2, opened the listening key Lk, and closed the ringing key Rk as here shown. Current now flows from $+B_2$ through CO_2–r_2–CL–j to $-B$, thereby lighting the calling supervisory lamp CL and closing the cut-off relay CO_2. The closing of CO_2 prevents the operation of the line relay LR_2 when subscriber 2 presently removes his receiver from its hook. Current also flows from the ringing generator through 5–f–t_2–l_2–bell and condenser in the subscriber's telephone–l_2'–s_2–g–4 back to the generator, thereby ringing the subscriber's bell, because this alternating current can readily pass through the condenser and bell. It will be seen that, when the operator

rings the desired subscriber, the ringing key breaks the circuit leading to the answering side of the cord circuit, and hence does not ring back in the waiting party's ear. The operator then releases the ringing key. When the called subscriber takes down the receiver R_2, current flows from $+B$ through x–d–6–f–t_2–l_2–P_2–c_2–T_2–l_2'–s_2–g–7–e–CR–z to $-B$, thereby operating the calling supervisory relay CR, which connects the resistance q in parallel with the calling supervisory lamp CL and causes the latter to go out. Hence, the going out of lamp CL signifies that the called subscriber has answered the telephone. Subscribers *1* and *2* can now converse, their circuits being practically the same as shown in Fig. 1.

When the conversation is finished, a supervisory lamp will light as each subscriber hangs up his receiver. For, suppose that subscriber *2* hangs up his receiver, current can no longer flow from $+B$ through x–d–6–f–t_2–l_2–P_2–c_2–T_2–l_2'–s_2–g–7–e–CR–z to $-B$, because this circuit is open at c_2. Hence, CR, being deprived of current, releases its armature, thereby opening the circuit through q and allowing the lamp CL to get enough current to light it. Similarly, the lamp AL will light when subscriber *1* hangs up his receiver. If only one lamp goes out, it usually signifies that the subscriber whose supervisory lamp remains lighted desires another connection. When both lamps are lit, the operator removes both plugs from the jacks and all circuits return to their normal conditions. Evidently, both supervisory lamps go out because their circuits are both open at the ring contacts of the withdrawn plugs.

17. Busy Test.—To explain the **busy test**, assume that the circuits are exactly as shown in Fig. 3, that is, subscribers *1* and *2* are connected together, subscriber *2* not having yet removed his receiver from the hook, and that the call of subscriber *3*, for connection with subscriber *2* whose line is now busy, has just been answered by an operator at another section of the switchboard. The latter operator makes the busy test as follows: Her listening key Lk' is

already closed because she has just been conversing with subscriber *3*. Leaving this key closed, she touches the tip t of her calling plug to the ring contact r_2' of the multiple jack in her section belonging to the line of subscriber *2*. Current flowing from $+B$ through the ground-CO_2-r_2'-r_2-CL-j to $-B$, makes the potential of the ring contacts of all jacks belonging to the line of subscriber *2* different from that of the ground and produces a click in the operator's receiver R'. For current then flows from $+B$ through n-ground-o-x'-d'-f'-t-r_2', where it unites with current that is flowing from $+B$ through n-ground-CO_2-r_2', and they flow as one current through r_2-CL-j to $-B$. Before touching t to r_2', the points d', e', and hence the terminals of the condenser C', had exactly the same potential difference as the terminals of the battery B', but now the current flowing from $+B$ through n-ground-o-x'-d'-f'-t-r_2'-r_2-CL-j to $-B$, has suddenly lowered the potential of the point d' and hence the charge on condenser C', has suddenly decreased, thereby producing a momentary current and click in the receiver R'. If the subscriber is listening at R_2, he will hear this busy test, because the winding x' of the repeating coil induces a momentary current in w', which flows through the subscriber's circuit and back through y' and B' to w'. If the test shows the line to be busy, the operator so informs subscriber *3*, and if no request for another connection is immediately made, she returns both plugs to their normal positions.

If the receiver R_2 has been removed from the hook, the test will be practically the same, the only difference being that the resistance q is now in parallel with CL. If the line is not busy, no click will be heard in the operator's receiver R', because, there being no plug in jack J_2, r_2 has the same potential as $+B_2$, that is, the same potential as the ground, and t also has the potential of $+B'$, which is identically the same battery as B_2, and hence the difference of potential between points d' and e' does not change at all when t is touched to r_2'. Although a subscriber may have removed his receiver from the hook, his line will not test busy until a plug is inserted in one of the jacks belonging to his line.

ANTI-SIDE-TONE OPERATOR'S CIRCUIT

18. The **anti-side-tone operator's circuit,** known as the **No. 24 induction coil,** and in use in 1905 in many of the New York Telephone Company's exchanges, is shown in Fig. 4. The primary winding is divided into two equal coils p, p' connected in parallel and the secondary consists of the two coils $a\,b$, $b\,c$ connected in series. The operator's receiver forms a shunt around a non-inductive resistance r of about 390 ohms and the secondary coil $b\,c$ of 130 ohms.

In the older arrangement the primary coil practically consisted of the two coils p, p' connected in series. With the

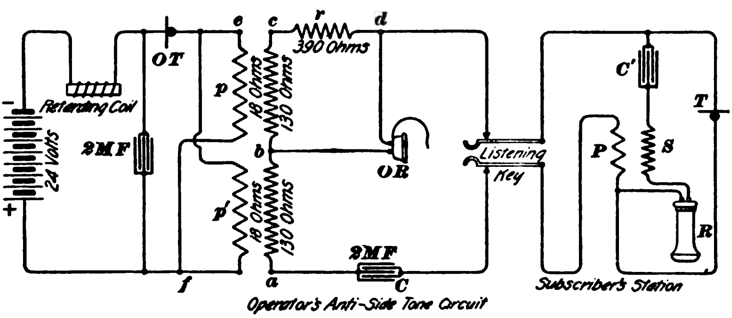


FIG. 4

two halves connected in parallel, as here shown, the inductive action on the secondary of both halves will be about the same as before. The condensers C, C' tend to neutralize the inductance of the circuit d–C'–S–R–P–C–a–b, and consequently the impedance of this circuit is probably not much greater than that of the operator's receiver circuit b–$O\,R$–d. The difference of potential applied to the line circuit is that developed across $a\,d$, while that applied to the operator's receiver is only that developed across $b\,d$, which is less than one-half that across $a\,d$. Consequently, the line circuit receives the greater current because it has the greater potential difference applied to it. The resistance r is wound non-inductively because it is directly in the line circuit, as well as in the operator's receiver circuit, and both circuits should be kept as free from inductance as possible. Hence,

the operator's receiver is affected very much less by the operator's transmitter than in the former arrangement, where the operator's receiver is directly in series with the entire secondary winding of the operator's induction coil. Consequently, the side tones produced in the operator's receiver are considerably reduced by this arrangement without reducing the sound produced in the subscriber's receiver when the operator is talking.

The effect that incoming currents have on the operator's receiver is reduced but little, because the impedance of the operator's receiver is less than that of the circuit $d c b$ that it shunts.

SUPERVISORY PILOT LAMP

19. A slightly different cord circuit involving several additional features is shown in Fig. 5. For each operator's position, there is usually one **supervisory pilot lamp,** which is associated only with the answering side of the cord circuit. The middle of the winding of the supervisory pilot relay SR is connected to the negative terminal of the battery B, while one end of the relay winding is connected through the armature of AR to v and the other end to AL. When currents flows through the two windings i, o in parallel, the relay SR will not be energized because these currents will be circulating around the relay core in opposite directions, but if the circuit through the winding i is open at the armature of the relay AR and a current flows only through AL and the winding o, the relay SR will be closed and the supervisory pilot lamp will light. The supervisory pilot lamp will remain lighted as long as any answering supervisory lamp in that operator's position remains lighted; this enables the supervising operator to see whether the operator is promptly withdrawing the answering plugs when the conversation is finished. Only one supervisory pilot lamp is necessary at each operator's position.

Although the resistances u, v, in the answering side of the cord circuit, are connected a little differently than the similar resistances j, q in the calling side of the cord circuit, it will be

seen that they accomplish exactly the same purpose. The arrangement shown allows the use of one supervisory pilot relay SR for all the answering cord circuits at one operator's position. The wires from the armatures of all answering supervisory relays AR at one operator's position are connected together at d and to the end of the winding i and all wires from the answering supervisory lamps AL at the same operator's position are connected together at e and to the end of the winding o.

20. A breastplate-transmitter and head-receiver set connected by a flexible cord to a twin, or double, plug (shown as two separate plugs in Fig. 5 for the sake of clearness) is provided for each operator. Although only one operator's twin jack J is shown (being represented in this figure as two separate jacks), there are, in most large exchanges, two sets of twin jacks connected in parallel at each operator's position, so that a supervising operator can plug in her talking-and-listening set and assist the operator during extra busy periods. It will be noticed that the transmitter battery circuit is closed only when the operator's twin plug is in its jack.

The **ring-down key** is for use at night when there are but few trunk or recording operators on duty. The other end of the order wires may be connected at night by means of switches with bells, so that the subscriber operator can call a trunk, or recording, operator at the other end of the order wire by closing the ring-down and proper order-wire keys. By closing both the listening and ring-down keys, it is possible to ring back through the repeating coil and the answering side of the cord circuit to the original calling subscriber's line. To avoid complication, two ringing generators G, G_1 are shown, but they are the same machine. The ringing key will be explained in connection with the two-party-line circuit.

A lamp RL and also a resistance may be inserted in the ringing generator circuit. They are adjusted to allow sufficient current to flow in the longest or highest-resistance line circuit, and the lamp, which is located in the testing room,

serves as a sort of tell-tale signal. If it remains lighted an undue length of time and is more brilliant than usual, there is probably a short circuit at some ringing key or elsewhere in the generator circuit. Moreover, a resistance in the generator circuit causes variations in line resistance to have less effect on the strength of the ringing current, and hence line crosses cannot cause an injuriously large current to flow from the generator through any apparatus in the switchboard.

BELL PARTY-LINE SYSTEMS

TWO-PARTY-LINE CIRCUIT

21. Several party-line systems controlled by the Bell Company and suitable for use with its central-energy system will now be considered. In large exchanges, a very simple two-party-line arrangement has been quite extensively used. The ringing circuit of one telephone is connected between one side of the line and the ground, while the ringing circuit of the other telephone is connected between the other side of the line and the ground. By connecting an ordinary alternating-current ringing generator between the ground and one or the other side of the ground, either telephone bell may be rung, the other bell remaining silent.

The arrangement of ringing keys to give this two-party selective ringing is shown in Fig. 5. The leads of the ringing keys *Ra*, *Rb* run to the generator *G*, which is an ordinary alternating-current ringing machine, having one side grounded through a lamp *RL*.

Many Bell Companies use two-party-line systems with a 1,000-ohm bell between each side of the line and the ground, and four-party-line systems with two 1,000-ohm bells between each side of the line and the ground. In the latter system, it is necessary to put 6,000 ohms in each bell circuit; because, otherwise, the resistance across the line would be low enough to keep the line relay closed, for it will attract its armature through about 1,500 ohms. The ten-party-line system used in Chicago has five bells between each side of the line and ground with a 2-microfarad condenser in each bell circuit.

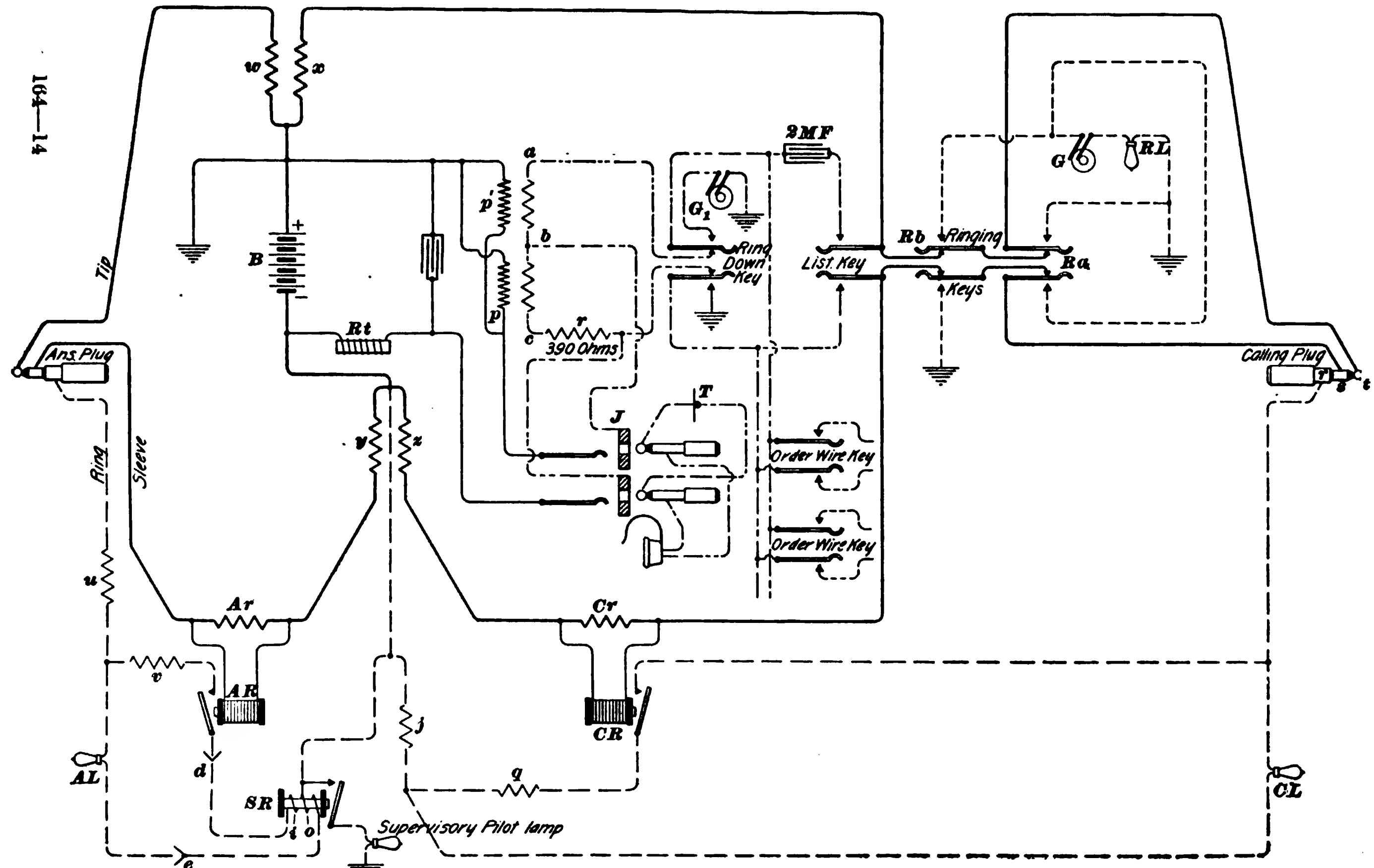

Tip
Ans. Plug
Ring
Sleeve
w
x
B
Rt
p'
p
a
b
c
r
390 Ohms
G1
Ring Down Key
2MF
List. Key
Rb
Ringing
Keys
Ra
G
RL
Calling Plug
T
J
Order Wire Key
Order Wire Key
y
z
u
Ar
Cr
v
AR
CR
j
q
d
AL
SR
Supervisory Pilot lamp
CL
e

FIG. 5

164—14

22. Party-Line Instruments.—In Fig. 6 are shown two party-line telephones *A*, *B*, the wiring of which differs from that shown in Fig. 1, in that the bell circuits are not bridged across the line, but connected from one or the other side of the line to the ground. At station *A*, it is connected from the *l'* side of the line; while at station *B*, it is connected to the *l* side. In Fig. 5, the ringing key consists of two parts, *Ra* and *Rb*. When an operator rings with the *Ra* side of the key, the ringing generator *G* is connected between the ground and the sleeve side of the

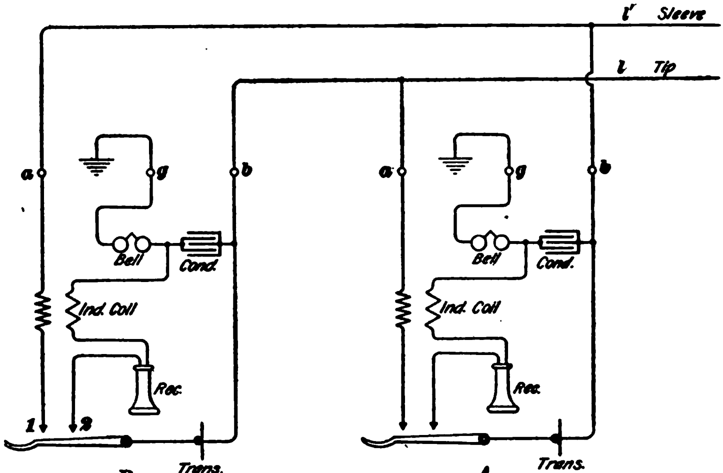


FIG. 6

cord, which we will say is connected to the *l'* side of the line in Fig. 6. Reaching station *A*, the current will flow through the condenser and bell to ground. On the other hand, the *l'* side of the line is open at *1* at station *B*, so that the bell there cannot be rung. If the operator rings with the *Rb* side of the key, the generator will be connected between the ground and the tip side of the cord, and the current will pass out on the *l* side of the line, through the condenser and bell at station *B* to ground. It will find no closed path through station *A*. By this arrangement, it is therefore possible to ring the bell of either one of two instruments properly connected to the same line circuit and, moreover, the two sides

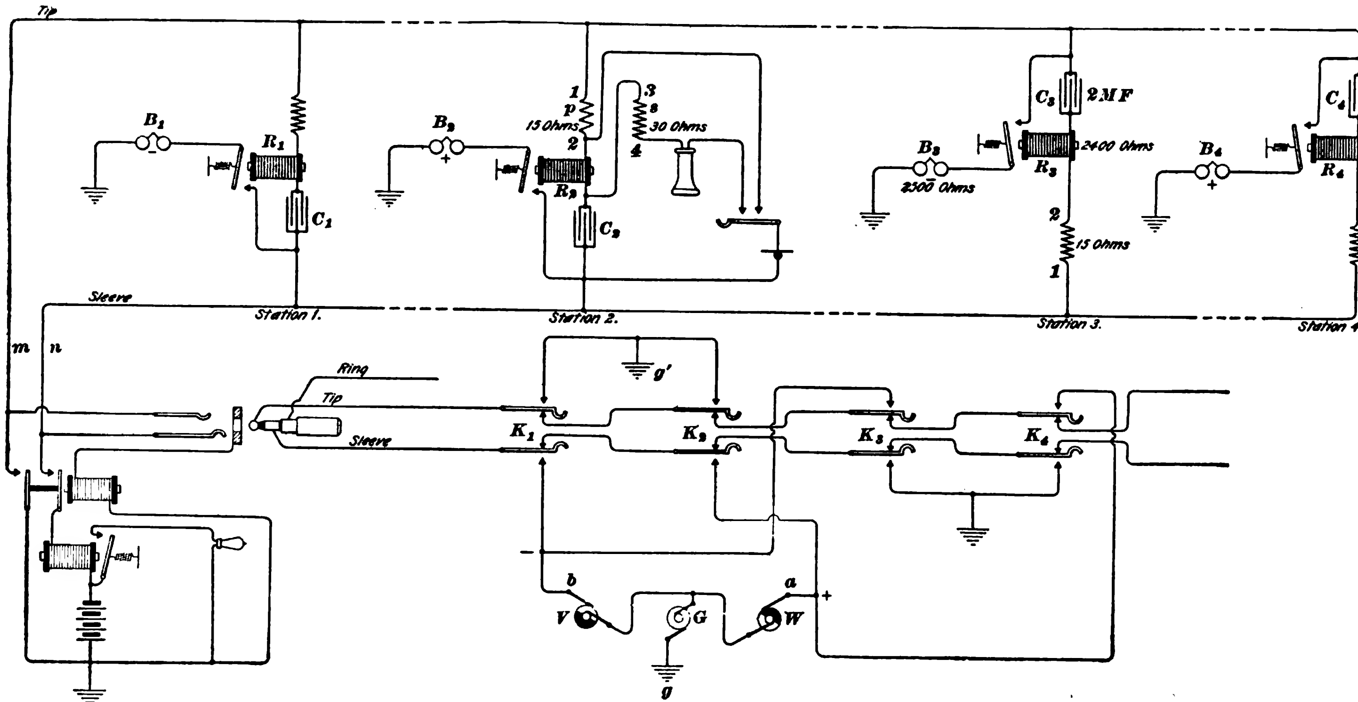

Tip
B1
R1
C1
B2
+
1
p
15 Ohms
2
R2
C2
3
s
30 Ohms
4
C3
2MF
B3
2500 Ohms
2400 Ohms
R3
2
15 Ohms
1
C4
B4
+
R4
Sleeve
Station 1.
Station 2.
Station 3.
Station 4.
m
n
Ring
Tip
Sleeve
g'
K1
K2
K3
K4
b
a
+
V
G
W
g

FIG. 7

of the line circuit are used as a complete metallic circuit for all conversations during the time the receivers are off the hooks.

THOMPSON SELECTIVE-SIGNALING SYSTEM

23. The **Thompson selective-signaling four-party-line system,** as applied to the Bell central-energy system, is shown in Fig. 7. At each subscriber's station, a relay, a primary winding of the induction coil, and a condenser in series are connected across the two line wires; the talking circuit, being the same at all stations, is shown only at station *2*. The signaling circuit at station *3* is just the reverse of that at station *1* and that at station *4* is the reverse of that at station *2*. The only difference between stations *1* and *2* and between *3* and *4* is that the bells at stations *1* and *3* are biased so as to be rung only by negative pulsating currents, while those at stations *2* and *4* are biased for positive pulsating currents. An ordinary alternating-current ringing generator G is connected between the ground and two brushes a, b on two commutating devices V, W mounted on the same shaft. The brush a is connected to the generator during the half revolution that a positive impulse is being generated by G and b during the half revolution that a negative impulse is being generated by G.

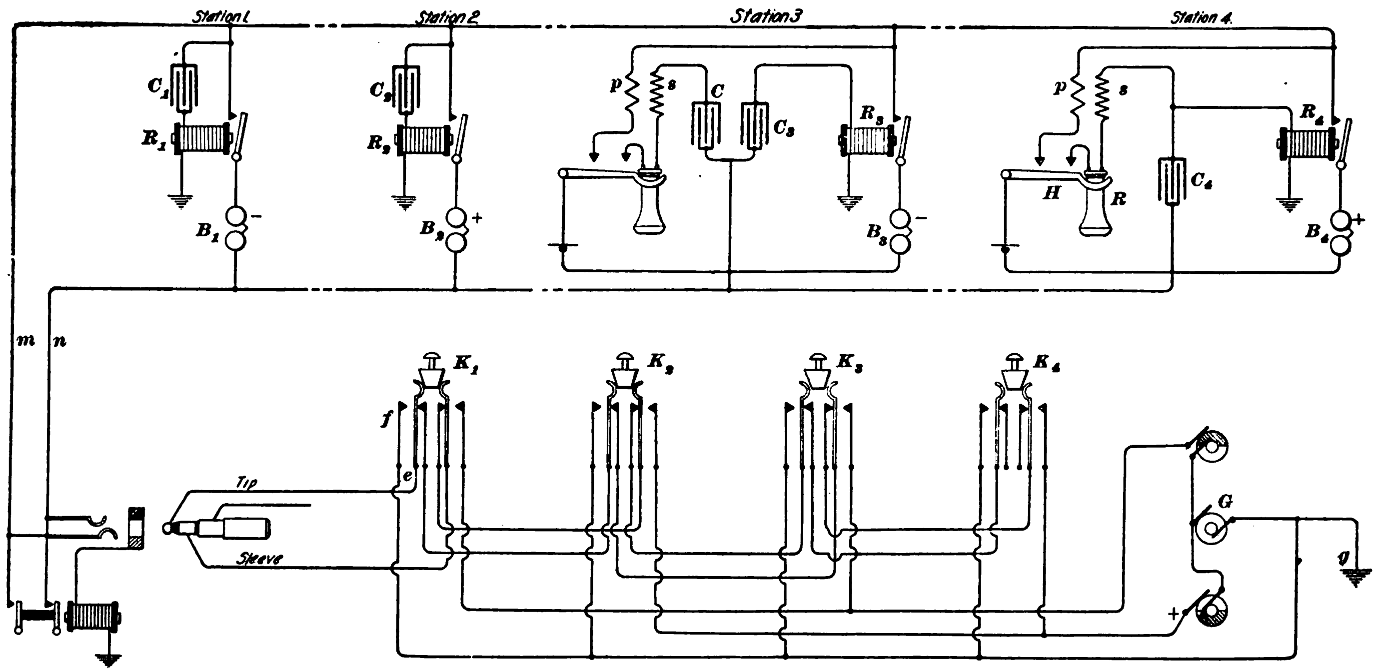
Mr. W. W. Dean devised a sluggish-acting relay especially for use at R_1, R_2, R_3, and R_4 in the subscribers' instruments. The armature is large, heavy, and pivoted so as to swing through a small arc; the momentum of the armature is so great that it will hold the circuit closed without quivering or vibrating when an alternating current passes through the relay coil. *1, 2* is the primary winding and *3, 4* the secondary winding of the subscriber's induction coil.

24. When a plug is inserted in the jack and the ringing key K_1 is closed, a negative pulsating current flows from the generator G through the sleeve side of the line n–all four relays R_1, R_2, R_3, R_4 in parallel–tip side of the line m–g'–ground–g to generator G. All the relays attract their

armatures, thus allowing negative pulsating currents to flow through the biased bells B_1, B_2 and back through the ground to G. B_1 is biased by a spring on one end of the armature so that these negative impulses will ring it, while B_2, being biased by a spring on the other end of the armature for positive impulses, will not ring. By closing key K_2, positive impulses from generator G flow over line n and ring only B_2. The bells B_3 and B_4 being shunted by the low resistance of the one line wire m will not receive enough current to ring in either case mentioned. By closing K_3, negative impulses from G flow over line m and back through all the relays and line n, thus closing the relays and allowing current to flow also through bells B_3, B_4 and the ground. Only the bell B_3, which is properly biased for negative impulses, will ring; whereas B_4, which is biased for positive impulses, will only be rung when key K_4 is closed. The principal advantage claimed for this system is that the main circuit, in its normal or unused condition and when actually in use as a talking circuit, is free from and undisturbed by earth connections, and is therefore in a condition of higher efficiency than otherwise would be the case. The chief objection to this and all other systems using relays or extra apparatus adjustable in character is the extra expense and complication in the apparatus outside the exchange; thus, maintenance and trouble are not reduced to a minimum.

STRYKER SELECTIVE-SIGNALING SYSTEM

25. The selective-signaling system shown in Fig. 8 has been devised by Mr. B. Stryker for use with the Bell central-energy systems. In the Thompson selective-signaling system, a relay in series with a condenser is bridged across the two line wires at each of the four stations. When the four relays are energized, they connect two biased bells, one of each polarity, between each line wire and the ground; and by sending a pulsating current in the proper direction over either line wire, the ground being used as a return circuit, any one of the four bells may be rung. It is claimed by Mr. Stryker



Station 1
Station 2
Station 3
Station 4.
C_1
R_1
B_1
C_2
R_2
B_2
p
s
C
C_3
R_3
B_3
H
R
C_4
R_4
B_4
m
n
K_1
K_2
K_3
K_4
f
e
Tip
Sleeve
G
g

FIG. 8

that if a considerable and variable potential exists between the various station grounds, due to an electric-railway system, for instance, the direct currents thereby produced will, at times, completely overpower the selective-signaling currents through the grounded bell circuits, either preventing the ringing of the bells or producing false signals. Stryker's system, which is claimed to overcome this trouble, consists of a sluggish-acting relay in series with a condenser at each station. At two stations, the relay and condenser are connected between one line wire and the ground, and at the other two stations between the other line wire and the ground; a relay when energized connects its bell across the two line wires.

26. Two ways in which the talking circuit may be connected are shown at stations *3* and *4*. Pulsating currents through the sluggish-acting relays R_1, R_2, R_3, and R_4 will hold them closed. When the ringing key K_1 is closed, a negative pulsating current flows out over line m, through condensers C_1, C_2, relays R_1, R_2, and the ground back to the generator G. The ground path being sufficiently less in resistance than the path through the condensers and relays at stations *3* and *4*, not enough current will return through the grounds at stations *3* and *4* and line n to operate the relays R_3 and R_4. The negative pulsating currents can now flow from line m through bells B_1 and B_2, returning through line n–e–f, but will only operate B_1, because B_2 is not biased for negative impulses. Closing key K_2 will operate relays R_1 and R_2, but will only ring the bell B_2, because a positive impulse now flows over line m, returning through ground and line n. Similarly, closing key K_3 or K_4 sends negative or positive impulses, respectively, over line n, energizing, in each case, both the relays R_3 and R_4; the negative impulses ring B_3 and the positive impulses ring B_4.

Trouble due to earth currents in the bell circuits is eliminated by the condenser in the grounded relay branch at each station and also, if necessary, by the extra condenser C, in the talking circuit, as shown in the receiver circuit at station *3*

only. By the use of the condenser C, a metallic connection between line m and the ground is avoided; whereas, with the arrangement shown at station *4*, there is a metallic path, when the receiver is off the hook, from line m through p–H–R–s–R_4 to the ground. The extra condenser C would be used in the receiver circuit, as shown only at station *3*, either at all the stations on the same line or at none of them.

O'CONNELL SELECTIVE-SIGNALING SYSTEM

27. In common-battery instruments in which a condenser is connected in series with the bell, it is impossible to ring the bells with pulsating currents flowing in one direction only, because the first impulse charges the condenser and it has no opportunity to discharge before the next impulse arrives. Mr. J. J. O'Connell has devised an ingenious arrangement for overcoming this difficulty, which, it is claimed, permits the bells on selective-ringing party lines to be worked as satisfactorily with intermittent, or pulsating, currents in one direction as with alternating current. It consists of a shunt resistance that is closed around the condenser as each impulse passes through the bell.

28. The arrangement applied to the Bell central-energy system is shown in Fig. 9. At station *1*, which requires positive-current impulses through the tip side of the line with the ground as a return to ring the bell B_1, a quick-acting relay R_1 is connected in series with the bell. When a positive impulse passes through the bell B_1 and relay R_1, one stroke is sounded on the bell and the relay also closes, thus allowing the condenser to discharge through the shunt resistance r_1, so that it is ready for another charge by the time the next impulse arrives. Both the bell and the relay armatures return to the normal positions during the interval of no current.

When key k_1 is closed, the sides of condensers C_1, C_2 connected to the tip side of the line become positively charged by ordinary conduction; by induction, this causes a negative charge to flow from the ground through R_1, B_1

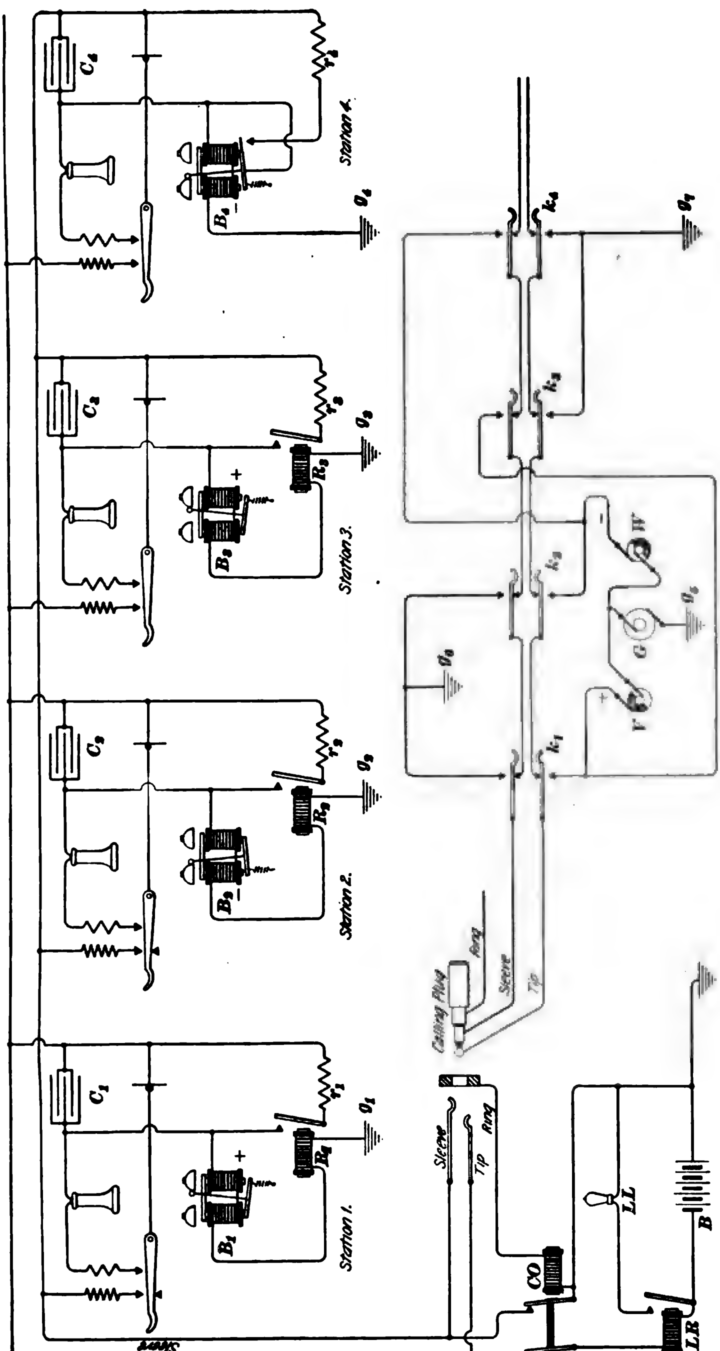

Station 1.
Station 2.
Station 3.
Station 4.
Calling Plug
Ring
Sleeve
Tip
Sleeve
Tip
Ring
CO
LL
LR
B
Tip
Sleeve

FIG. 9

and R_2, B_2 into the other side of condensers C_1, C_2, respectively, which is equivalent to a positive charge flowing through bells B_1, B_2 into the ground; hence, only the bell B_1 rings.

At stations *1* and *3* the same arrangement is used, except that bell B_1 is rung by a positive impulse over the tip side, and bell B_3 by a positive impulse over the sleeve side of the line. At station *4* is shown a slightly different arrangement that may be employed, in which the bell itself controls the shunt resistance. When a negative impulse comes over the sleeve side of the line, the bell B_4 gives a stroke and at the same time connects the shunt resistance r_4 around the condenser, which can thus discharge and be ready to receive the next impulse. A source of positive and negative impulses G, commutators V, W, and four selective-ringing keys k_1, k_2, k_3, and k_4 are provided.

29. Selective-ringing keys for use in each cord circuit with any selective-signaling party-line system should be designed so that the key pressed remains out of its normal position, but not closed, when released, but is restored to its normal position by the act of using any one of the other keys. This does not mean that the contact springs should remain out of their normal position, but only the key handle. By this arrangement, the operator can tell at a glance which key to use in case she has to ring a subscriber a second time; provided, of course, that there is a complete set of ringing keys for each cord circuit, and not merely one master key for each operator's position.

O'CONNELL PARTY-LINE JACK AND TONE-TEST CIRCUITS

30. O'Connell Arrangement of Party-Line Jacks. It is possible to arrange two-party and four-party biased-bell systems so that the work of the operator in connection with such lines may be uniform with that on individual lines. An arrangement devised for this purpose by Mr. J. J. O'Connell provides one line signal and answering jack for each party line at one section of a multiple switchboard and as many jacks in the multiple portion of each section as there are

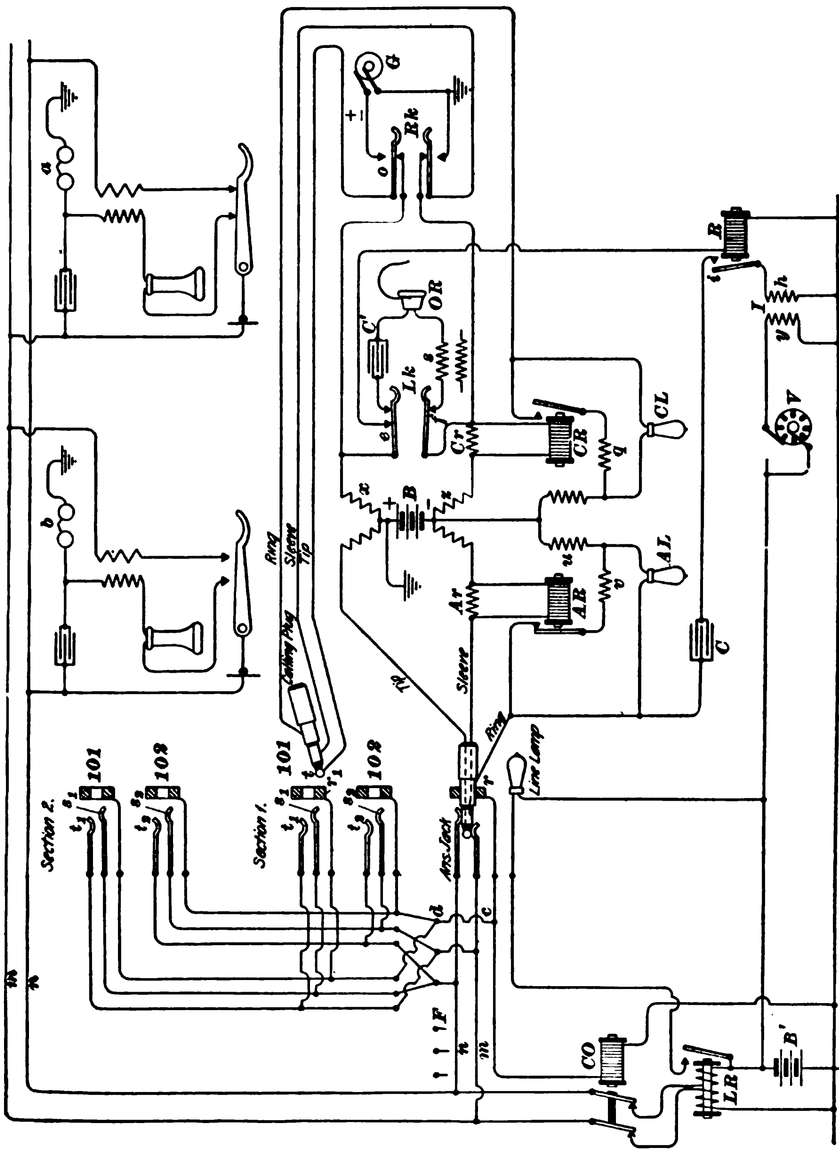

Section 2.
Section 1.
101
102
Calling Plug
Ring
Sleeve
Tip
Ans. Jack
Line Lamp
Rk
OR
Lk
Cr
CR
CL
AR
AL
Ar
B
B'
CO
LR
C
V
G

FIG. 10

stations on one line. The arrangement for two-party service is shown in Fig. 10, in which two sections of a multiple switchboard, two stations on one party line, and one cord circuit are represented.

31. The line is connected to two jacks in the multiple at each section in addition to an answering jack at one position. The tips t_1, t_1 of one jack at each section and the sleeves s_2, s_2 of another jack at each section are connected to the same line wire m, and the sleeves s_1, s_1 of one jack at each section and the tips t_2, t_2 of another jack at each section are connected to the other line wire n. The line relay LR is shown with two equal coils, one connected in each side of the line circuit. The use of two coils, which are connected so as to assist each other in magnetizing the core, balances the line circuit better than one coil in one side only, but the operation of the line circuit is exactly the same as already explained, where one-coil line relays were shown.

32. The sleeve of each calling plug is always connected to ground and the tip to the alternating-current generator G when the ringing key is closed for ringing on any party or private line. The operator is only provided with one ordinary ringing key for each cord circuit; no special party-line ringing key of any kind is necessary. When the calling plug is placed in jack *101* at any section, an alternating current will flow over line m and ring bell a; when placed in jack *102* at any section, an alternating current will flow over line n and ring bell b.

The arrangement of the multiple jacks is the same, as far as the operation is concerned, as if there were two separate lines instead of one, except that the rings of all jacks belonging to the same line circuit are connected together. This arrangement makes it a simple matter to transfer all multiple jacks having the same number from one party line to another when a subscriber moves and his telephone is connected to a different party line. This change is made at the intermediate frame F by means of three jumper wires and the subscriber retains the same telephone number.

33. Reverting Calls.—A call from one party on a party line for another party on the same line is termed a **reverting call.** An operator completing a call would not necessarily know that the multiple jack for whose number she has a call belongs to a party line, because the different subscribers on a party line in this arrangement have different numbers and different jacks in the multiple, which are exactly alike as far as she can see. Furthermore, some means must be provided to inform an operator when she tests a party-line multiple jack whether that jack belongs to the same line as the answering jack through which she has just received the call; in other words, whether it is a reverting call. Otherwise, when she tests the multiple jack to complete a reverting call, she would get the ordinary busy signal, which would lead her to incorrectly inform the calling subscriber that the party desired was busy. In other words, it would practically prevent any communication between two parties on the same party line. To avoid this difficulty, an additional **party-line tone test** has been devised by Mr. O'Connell, which will inform an operator of the condition of the line when she starts to complete a reverting call.

34. O'Connell Party-Line Tone Test.—Each cord circuit for use with O'Connell's arrangement of party-line jacks, shown in Fig. 10, is equipped with an extra relay *R* and a condenser *C*, while the whole switchboard is provided with one repeating coil *I* and one current-interrupting device *V*. The coils *v*, *q* have a resistance of 20 ohms, instead of the usual 40 ohms, in order to give sufficient current to operate the relay *R* very quickly. The listening key *Lk* has an extra contact *e* connected with the relay *R*, which is constructed to be very quick in acting. The circuits are the same as in the standard Bell central-energy system, except where already mentioned. An operator serving no party lines does not require the extra equipment mentioned.

35. Operation.—Assume that subscriber *102* has called for subscriber *101* and that the operator has inserted an answering plug in the answering jack. This will put the

ordinary busy test on all jacks associated with that line and should any other operator test any of these jacks she will get the usual busy-test click, probably a little more intense. The answering operator now closes her listening key Lk and touches the tip t of the calling plug to the ring r_1 of the jack of the subscriber desired, not knowing necessarily that subscribers *102* and *101* are associated with the same line. A current from B' interrupted by the device V, flows all the time through the winding y of the repeating coil I and now current will flow from B through $u-\left\{\begin{matrix} v \\ AL \end{matrix}\right\}-r-c-CO$ to ground, thus making the potential of all the jack-rings associated with the same line different from that of the ground, and hence current will also flow through $c-d-r_1-t-o-\left\{\begin{matrix} e-R \\ x \end{matrix}\right\}$ to ground. This will cause R to attract its armature and allow an alternating current to flow from h through $i-C-r-c-d-r_1-t-o-e-C'-OR-s-f-C-r-z-B-$ ground to h, thus producing a musical tone in the operator's receiver OR, which signifies that the tested line is in use by her own answering plug and that she can therefore complete the connection. She will also get the usual busy-test click and some current from h will flow through $c-CO$. On receiving the tone test, the operator inserts the calling plug into the jack tested and tells the calling subscriber to hang up his receiver while she rings up the party desired.

If the operator tests any line that is not busy, the relay R will not be energized; if she tests a party line that is busy on account of a calling plug being in a multiple jack at any section, or an answering plug in an answering jack at any other section than her own, the relay R will close, but she will get no tone test, merely the ordinary busy-test click, because all the other listening keys and hence all the other R relays will be open. The operators only have to remember that the regular click means a busy line and the tone test a reverting call.

36. A tone test, instead of a regular busy test, might occasionally be received by an operator while testing a

multiple jack of a party line at exactly the same time that another operator, who had just previously inserted her answering plug in the answering jack of the same line, was also making a busy test on another multiple jack of the same line. In this case, both operators would receive the tone test and both would proceed to complete the call. Moreover, while an operator is testing any busy jack whatever, the tone test is applied momentarily to the rings of all jacks associated with the answering jack in which the answering plug is inserted, whether it is a party or private line. This might, at some other section, give a tone test at a multiple jack associated with the answering jack if both operators tested at the same instant, instead of the correct busy-test click.

37. As the length of time during which the tip of a plug is in contact with a jack when making a busy test is very short, the relay *R* must operate very quickly so as to give the tone test almost instantly. For this reason, the potential of busy jacks is increased more than usual by using a resistance of 20 ohms at *v* instead of the usual 40 ohms. The relay *R* may also be made to respond more quickly by making it more sensitive and providing it with a lighter armature. The method of operating party and individual lines is the same, and directory numbers for the party and individual numbers will be of the same general character.

38. Arrangement of Jacks and Ringing Circuit for Four-Party Lines.—The same advantages may be obtained on four-party lines by the arrangement shown in Fig. 11. Since pulsating currents are used, no condensers are shown in the bell circuits, although condensers would be used in the Thompson and similar party-line systems. The tip springs of jacks *a*, *c* are connected to line wire *m* and the sleeve springs to *n*; while these connections are reversed for jacks *b*, *d*, their tip springs being connected to *n* and their sleeve springs to *m*. The test thimbles of jacks *a*, *b* are connected to ground through a resistance *e*, while the test thimbles of *c*, *d* are connected through the two resistances *f*, *e*

in series to ground. The resistance *e* may be the winding of the usual line cut-off relay in the Bell central-energy system. The calling end of the cord circuit shown in the figure is provided with a single ringing key and a relay *R* that receives enough current to operate it only when connected in series with the one resistance *e*. The depression of the ringing key always connects the tip to ground and the sleeve to the ringing generator. If the plug is placed in jack *d* or *c*, the relay *R* will not be operated; hence, in either case, when the ringing key is closed, positive pulsating current will flow

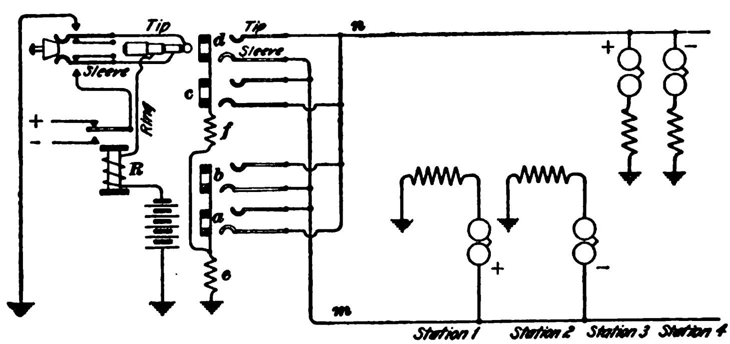


FIG. 11

to the sleeve of the plug; when in jack *d*, the positive pulsating current flows out over line *m*; when in jack *c*, over line *n*. When the plug is inserted in jack *a* or *b*, the relay *R* will be energized and hence connect the ring of the plug, when the ringing key is closed, to a source of negative pulsating current; consequently, this current will flow over line *m* when the plug is placed in jack *b* and over line *n* when inserted in jack *a*. Hence, the operator rings over such party lines in the same manner as on individual lines, requiring, therefore, no extra mental exertion on her part.

39. As to whether the extra cost of four jacks and at least one extra resistance in such line circuits, a relay in each cord circuit, and the extra complication is warranted by the better service obtained must be decided in any given case. The jacks can be arranged for a multiple switchboard and the

operation of testing and ringing is practically the same as on private lines, with the addition of the party-line tone test that is used to indicate a reverting call.

TEN-PARTY-LINE SYSTEM

40. Two-, four-, and ten-party-line circuits have been extensively used by the Chicago Telephone Company, the ten-party-line instruments being equipped almost invariably with a nickel-in-the-slot collecting device. On the ten-party-line systems, the bells of five stations are bridged from each line wire to the ground, and when any bell is rung, the four other bells on the same side of the line also ring. Each subscriber on a side has a certain number of rings to which no other subscriber is supposed to respond.

41. **A ten-party-line ringing key** devised for this purpose by Messrs. C. E. Scribner and F. R. McBerty (patents Nos. 751,566 and 751,539) enables the operator to transmit to the party line any form of code ring, such as a varying number of rings of long or short duration, and without the necessity of pressing the ringing key a number of times; and it also provides the operator with a method whereby she may know what party she rang last in case it is necessary to repeat the ring. By turning the handle to any one of five positions on the left of its normal position, the operator may give any one of five rings over the tip side of the line, and, by turning to the right, any one of five rings over the sleeve side of the line. When the operator presses down the handle, the distance that it moves is limited by steps, which correspond to the number and duration of the rings to be sent over the line. As soon as the operator removes her hand from the key, a releasing mechanism commences to operate and allows the key to rise by successive steps, each step causing a ring of the proper length to be transmitted to the line. In the key is included an electromagnet, which forms a portion of the releasing mechanism. Such a key could be inserted in each cord circuit, or one such key could be used as a master key in each operator's position.

Since it is difficult to show the mechanism of this key in a figure, it will not be further described here.

42. Multiple Jacks for Party-Line Circuits.—In an exchange opened in 1903 by the Chicago Telephone Company, special provision was made for the party-line service. On the local, or subscriber, board, there is a separate multiple jack for each of the instruments on the four-party-line circuits. The ten-party lines are all brought to a so-called trunk board, where each subscriber has a separate multiple jack, as in the case of the four-party lines on the regular subscriber board. Only calls from, or for, the ten-party-line subscribers are handled at this board. A separate jack for each party-line subscriber not only reduces the number of operator's errors, but it also enables a subscriber to move anywhere in the same office district and still retain his own number, the change being made at the intermediate distributing frame, in the same manner as the single-party-line multiple jacks would be changed. All calls for subscribers on the ten-party lines are local trunked from the local subscriber or trunk board to the ten-party-line trunk board. The advisability of bringing direct trunk lines from the various exchanges directly to the ten-party-line trunk board was then being considered. Each position on the latter was equipped with fifteen pair of cords with regular listening and temporary manual ringing keys, which were to be replaced by the automatic ten-party-line ringing key described in the last article.

BELL CENTRAL-ENERGY SYSTEM

(PART 2)

TELEPHONE METERS

1. Records of the number of completed calls made by a telephone station each month or year are kept either by meter or by what is called *ticket making*, that is, each operator makes a memorandum of each call made by each subscriber and sometimes of the subscriber who is called. There have been a great variety of forms designed for this purpose, but none has as yet been entirely satisfactory. Where the meter method is in use, a button is associated with each pair of switchboard cords and a meter is associated with each measured-service line. When it is desired to register a call on a certain line, the operator presses a meter button associated with the pair of cords that is used in that particular call; this operates the meter, which is usually one of a bank located in the terminal room.

Registering meters, operated automatically or by the subscriber pressing a button when directed to do so by the operator, and coin-collecting devices are increasing in use and popularity. Such devices are placed on or alongside the telephone instrument.

BELL TELEPHONE SERVICE METERS

2. Service Meters.—As a great deal of the operator's time is used in writing out tickets for messages for which a fee is charged, telephone engineers have been trying for a number of years to devise a meter that will take the place of the hand-written ticket. The first meter devised and put

in operation was of the automatic type; that is, it was actuated by the operator performing the work necessary in handling the connection. It consisted of two coils, one of which (about 6.5 ohms in resistance) was in series with the cut-off relay, while the other (about 450 ohms in resistance) was bridged across the line-lamp circuit. The second coil was energized when the subscriber removed the receiver from the hook, and the first when the operator, in answering the call, inserted a plug in that subscriber's jack. These two coils worked a magnetic clutch that actuated a pointer that played over a dial. The removing of the receiver from the hook moved the pointer half a division, and the action of the operator in answering the call advanced it to the whole division mark. One of these service meters was wired to each

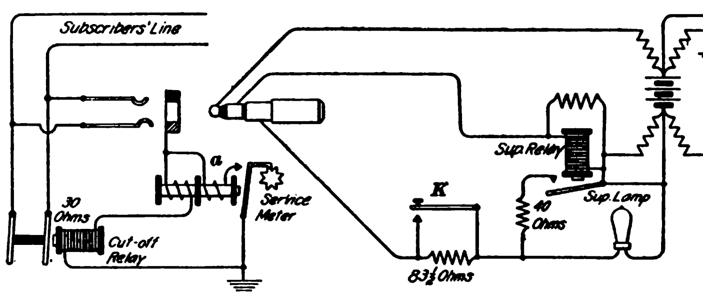


FIG. 1

subscriber's line. The great defect with this type of meter was that it recorded *lost calls*, that is, calls that were not completed on account of the called party failing to answer or on account of the line being out of order. After repeated trials, it was found better to depend on the operator to work the meter by depressing a key and to make its operation so simple as to be a material saving of time over the process of writing out checks. This is the type of meter used in 1904; the method of connecting it to the cord circuit is shown in Fig. 1. The meter is provided with two windings, one of which has a resistance of 500 ohms and the other of 40 ohms. The 40-ohm coil is wired in series with the cut-off relay, while the other *a* forms a shunt around both. A key is

placed on the keyboard opposite each end and wired so that when depressed it short-circuits the $83\frac{1}{3}$-ohm resistance, which increases the current sufficiently through the winding in series with the cut-off relay to operate the meter. Directly the armature is pulled up against the contact, the coil *a* is brought into play, thereby locking the meter. When the plug is withdrawn from the jack, the meter is released and records one call. Service meters have not proved entirely satisfactory to the New York Telephone Company.

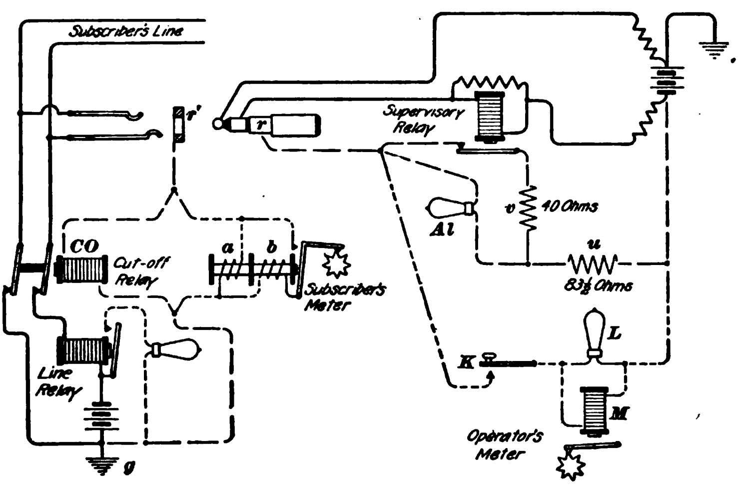


FIG. 2

3. Scribner & McBerty Meter Circuit.—The arrangement of circuits for a subscriber's meter associated with each line circuit and one operator's meter for each operator's position, devised by Messrs. Scribner & McBerty, is shown in Fig. 2. The subscriber's meter has a high-resistance winding *a* and a low-resistance winding *b*; the high-resistance winding *a* is connected as a permanent shunt around the cut-off relay, while the low-resistance winding *b* is normally open; but when the armature of the subscriber's meter is attracted, the low-resistance winding is connected in parallel with both the high-resistance winding *a* and the cut-off relay. The windings are so designed that when a plug is first inserted

and current flows through $u-\left\{\begin{matrix} v \\ A\,l \end{matrix}\right\}-r-r'-\left\{\begin{matrix} CO \\ a \end{matrix}\right\}-g$; the portion through the winding *a* is not sufficient to operate the subscriber's meter, but the portion flowing through the cut-off relay *CO* is sufficient to opérate it. When the operator closes the key *K*, the winding *M* of the operator's meter, which has a resistance of about 20 ohms, and the indicating lamp *L* form a shunt around the supervisory lamp circuit, thereby allowing sufficient current to flow through the high-resistance winding *a* to pull up the armature of the subscriber's meter, and thus closing the circuit through the low-resistance winding *b*, which locks the meter and allows the flow of sufficient current to light the lamp *L* and also to pull up the armature of the operator's meter. Consequently, the armature of the subscriber's meter is held up throughout the conversation and is only released and the meter operated when the plug is withdrawn from the jack.

Sufficient current flows through the cut-off relay to make it hold its armature as long as the plug remains in the jack. The lighting of the lamp *L* shows the operator that she has closed the key *K* to register the call and that the circuit is probably in working order.

4. In Fig. 3 is shown a somewhat different arrangement of the cord circuit, whereby neither the subscriber's nor the operator's meter will register a call until after the receiver at the station called has been removed from its hook. The armature *o* of an electromagnet normally locks the key *k* above it so that the operator cannot close it. *D* may be a direct-current dynamo of higher potential than the battery *B*, so as to better operate both the subscriber's and the operator's meters, or the battery *B* may be used, as in the preceding figure, to supply the current for this purpose. The locking electromagnet has two coils, one *m* of high resistance, say 200 ohms, and the other *n* of low resistance, the resistance of *q* and *n* together making about 40 ohms.

Assume that the answering plug *AP* is in the answering jack and that the calling plug *CP* has been inserted in a jack belonging to the line of the subscriber called. Current will

flow from *B* through the ground-cut-off relay *C O'* associated with the called subscriber's line-ring *r* of the calling plug-calling supervisory lamp *C l–j* to battery *B*; the armature *o* now locks the key *k* so that the operator cannot close it. When the called subscriber removes his receiver, the supervisory relay *C R* becomes energized. Current can then flow through *q–n*, which will cause the electromagnet to attract its armature *o*, thereby closing the circuit through *d–o–m*, through which enough current flows to enable the magnet to hold the armature *o* more securely than before. The operator can now close the key *k* and thus operate both the subscriber's line meter *M* and her own cord-circuit meter *O M*.

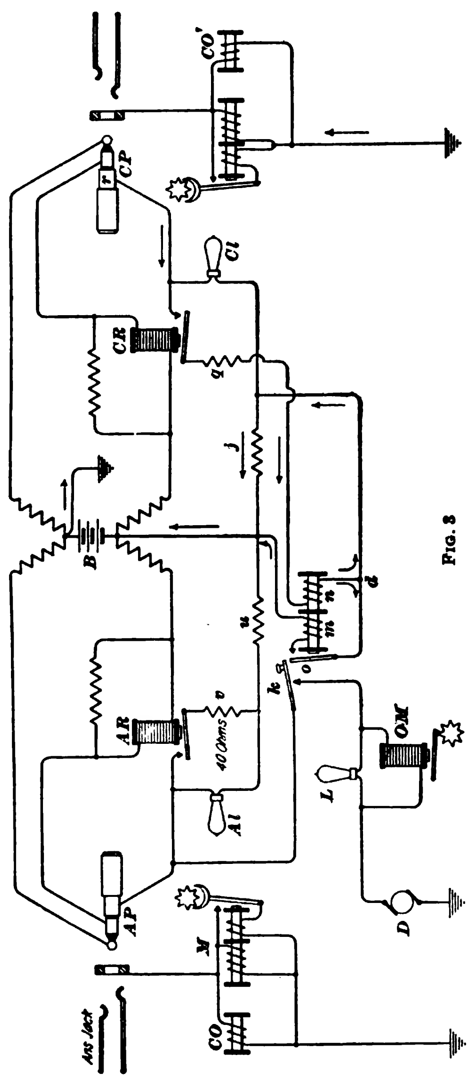


FIG. 3

5. The construction of a meter made by the Western Electric Company is shown in Fig. 4. When a current passes through the coil *M*, the armature *a* is

drawn toward the rounded end *d* of the core and a ratchet arm *c*, which is pivoted to one side of the armature, moves the ratchet wheel *e* one tooth forwards. The pawl *f* prevents any backward movement of the ratchet wheel. The contact at *b* is closed when the armature is attracted. The counting train is similar to that of an ordinary bicycle cyclometer, the number appearing through a glass, or mica, window on the face of the meter, as shown at *W*.

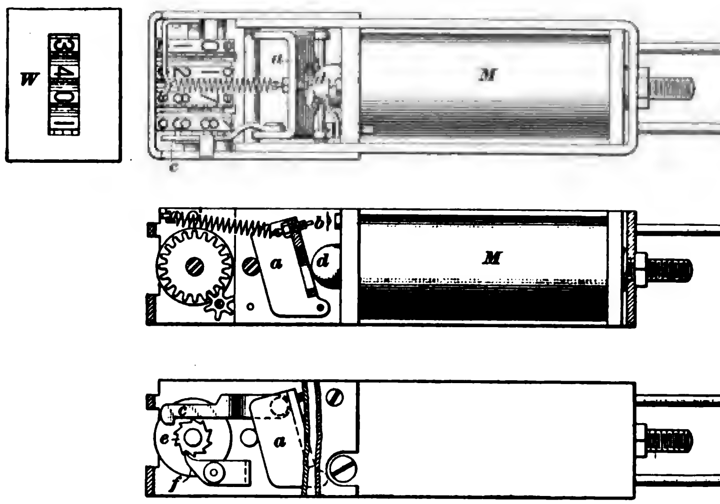


FIG. 4

6. Two-Party-Line Meter.—In Fig. 5 is shown an arrangement devised by C. E. Rodes for two-telephone meters, one for each of two subscribers on the same party-line circuit. The two meters, whose controlling magnets are *a* and *b*, are located at the central office. In connection with *a*, there is a locking magnet *n*, which, when sufficiently energized, prevents *a* from operating its meter. The magnets *b* and *n* are quick-acting, but require an extra strong current to make them attract their armatures; whereas *a* is very sluggish, but a very much smaller current will cause it to attract its armature. Two sources of direct current are provided, one *B'* of usual voltage (24 volts) and another *G*

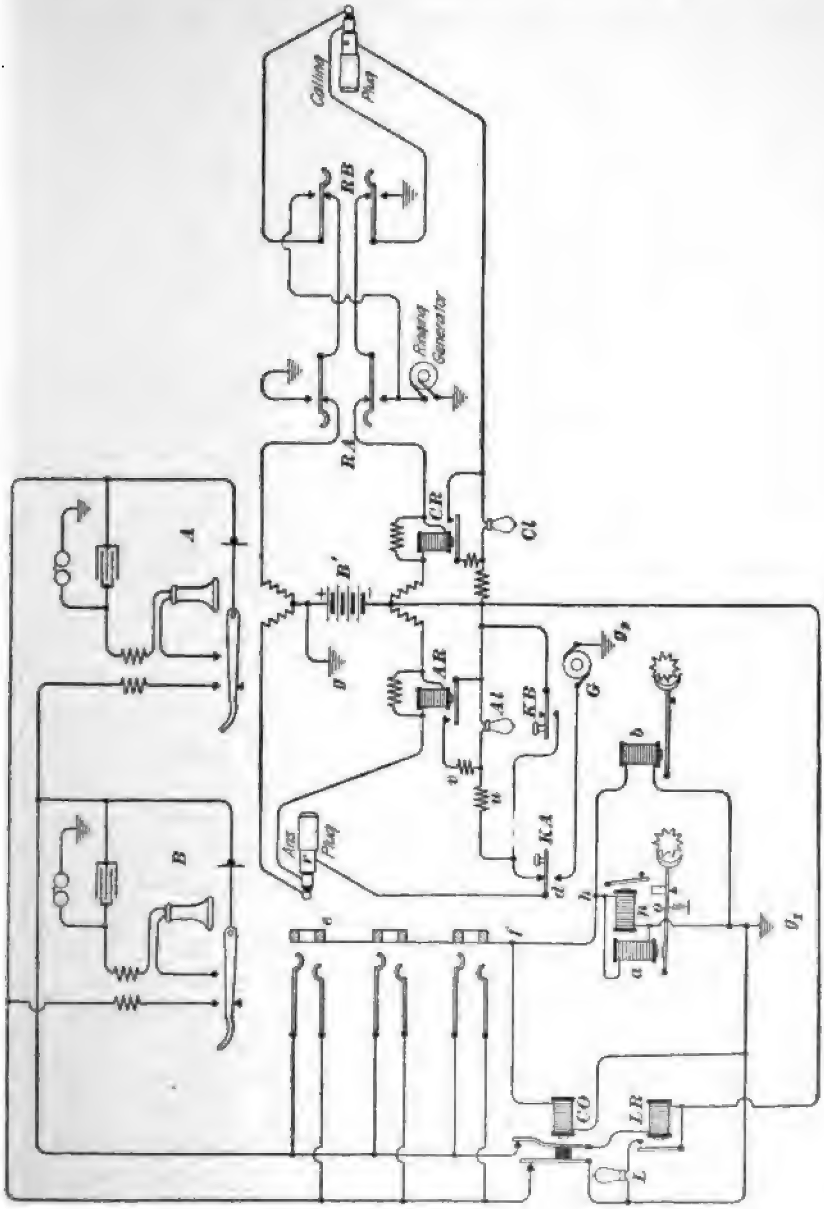

Calling Plug
RB
Ringing Generator
RA
CR
Cl
B'
AR
At
KB
G
Ans. Plug
KA
A
B
CO
LR
L

FIG. 5

of considerably greater voltage. All the meter magnets are connected in parallel with the cut-off relay and must, therefore, have sufficient resistance not to interfere with the operation of the cut-off relay and, moreover, the meter magnets must not be operated by the current that flows through them when the answering plug merely remains in the answering jack.

Assume that the answering plug is in the answering jack, that the party desired has been obtained by the operator, who then has the right to operate the calling subscriber's meter once. If A is the calling subscriber, the operator will press once the meter key KA. This will allow a strong current from the generator G to flow through d–r–e–f, where it divides through the four parallel circuits containing CO, a, n, b. Each meter magnet b, n, and a receives sufficient current to operate it, but n operates so much more rapidly than a that the latter's armature o is locked before it can operate the meter, hence only the meter controlled by the electromagnet b and the key KA is operated. If B is the calling party, the operator will press the button KB. This will short-circuit $u-\left\{\begin{matrix} v \\ A\,l \end{matrix}\right\}$, and thus allow the battery B' to furnish sufficient current to operate the magnet a, but not enough current to operate n or b; hence, only the meter controlled by a is operated. There is always sufficient current to enable the cut-off relay CO to hold up its armature. The ringing key RA, when closed, will ring only the bell of subscriber A, and RB only the bell of subscriber B, provided that the calling plug is inserted in a jack belonging to a suitable party-line circuit.

7. Four-Party-Line Meter.—For use on the Bell four-party-line circuits, J. L. McQuarrie has devised for the Western Electric Company (patent No. 794,112) a four-party-line meter. It is connected in parallel with the cut-off relay and consists of two polarized magnets that operate the four registering devices. The operator's cord circuit is provided with four keys—one sends a strong positive current through the meter magnets; a second key sends a strong

negative; the third, a weak positive; and the fourth, a weak negative current. Each current produces such a motion of the magnetic levers as to operate only one register. A bell with a distinctive tone is arranged in each party-line telephone, so that the operator answering the call causes the bell to ring or tap and can therefore hear the tone and thus know which key to press in order to register the call on the proper party's meter register.

COIN-COLLECTING DEVICES

8. Instead of placing recording meters associated with each line at the exchange, some companies prefer to use **coin-collecting devices** located at the telephone station. There are quite a number of coin-collecting meters now on the market; some of them are entirely mechanical and the operator tells whether the proper coin has been deposited by the sound made through the telephone by the coin as it strikes a gong of a certain tone. When electrical connections are used, they are usually very simple; but the mechanical construction is usually rather complicated.

NICKEL-IN-THE-SLOT METERS

9. **Nickel-in-the-slot meters** have been extensively used by the Chicago Telephone Company, one type of which is shown in Fig. 6. The directions on the box are as follows: First remove the telephone receiver from the hook, and when the operator answers "nickel" drop a nickel five-cent piece in the slot *x*. If the desired party is not obtained, the nickel is returned in the cup *o*. When through, hang up the receiver.

In the right-hand view is shown the shape of the coin slot. Coins smaller than a nickel will topple over sidewise, because the slot is inclined sidewise as shown, and fall out through the opening *v*. A nickel will follow the slot and is of proper weight to push before it the aluminum piece *w*, which is pivoted at *m*, enough to allow the nickel to drop down the chute *k* and rest on the top of *h*. The thickness of a nickel

is also sufficient to push n so that e touches f, thus closing the circuit u–c–b–f–e–q through the frame to g. If the coin is lighter than a nickel, it will not pass by the piece w; and if too thin, it will not close the circuit between e, f. a is the armature, p the permanent magnet, and c, b the coils of an ordinary polarized bell.

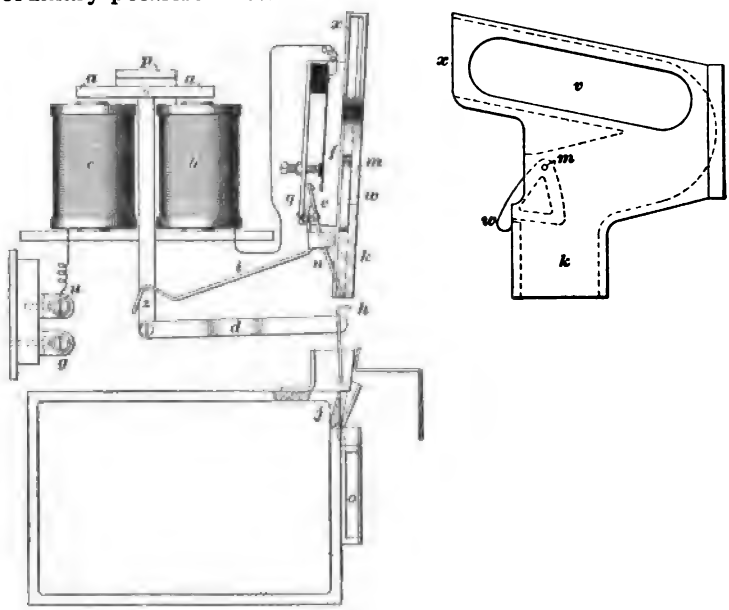


FIG. 6

10. The complete circuit is shown in Fig. 7. If the operator secures the party desired, she presses the proper key, say K, and if a nickel is in the slot so as to hold e against f a positive current flows from $+G$ through the winding v of a relay–tip side l of line circuit–winding p–contacts $2, 1$–coils c, b of polarized ringer magnet–f–e–q to ground g. This causes the armature a to be attracted by c, the pin z raises the lever i so as to securely hold e against f and the piece d pushes h to the right, thus allowing the nickel to fall into the coin box. The current through v causes the lamp L to light, thus informing the operator that a nickel or a piece of metal of the same size, weight, and

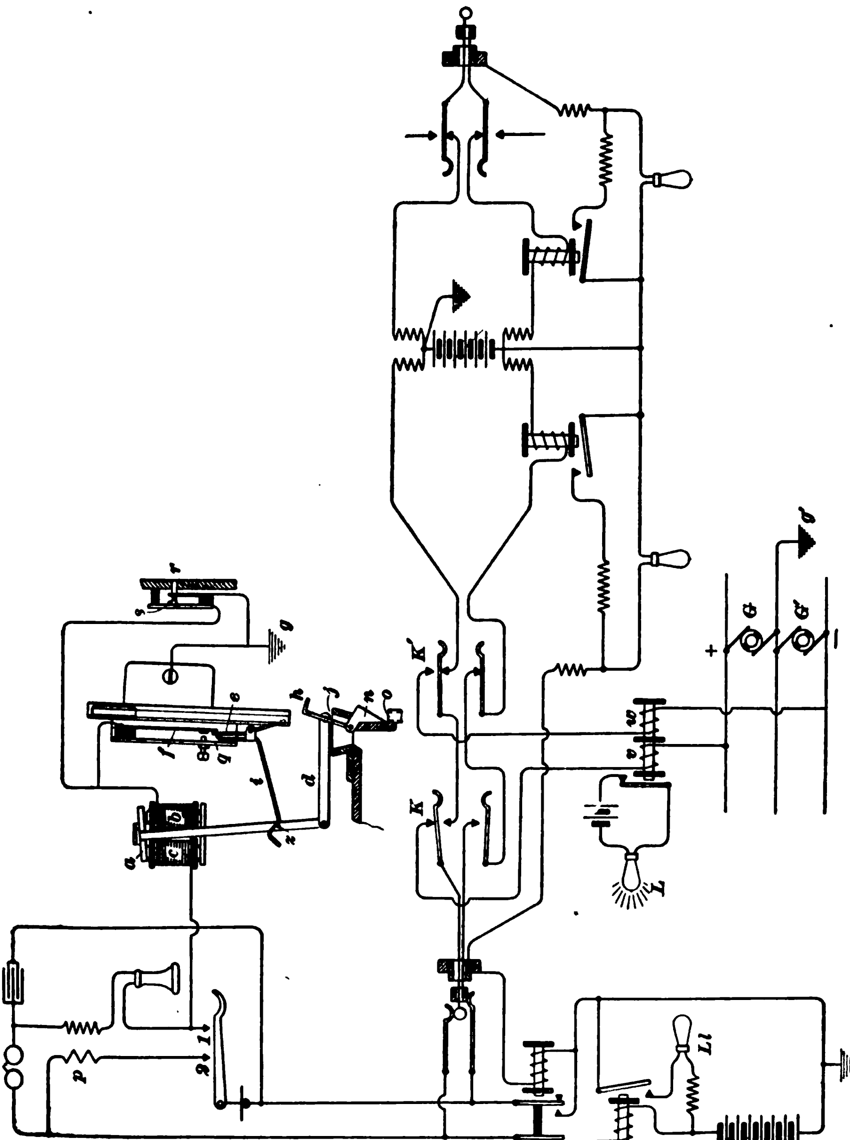


FIG. 7

shape has been deposited in the slot, because otherwise the circuit would be open at *f* and no current could flow through *v*. When the operator releases the key *K*, the spring and weights of the various parts of the slot device restore all parts to their normal positions.

If the party desired cannot be secured, the operator closes the key *K′*, which allows a negative current to flow from $-G'$ through *w*–tip side *l* of line circuit–*p*–*2*–*1*–*c*–*b*–*f*–*e*–*q* to *g*. This current, flowing in the opposite direction to the former current, causes *b* to attract *a*, the pin *z* raises the lever *i* so that *e* is held firmly against *f* and the arm *d* pulls *h* to the left, thus dropping the nickel on the right of the edge *j* behind the freely pivoted piece *n* into the cup *o*, where it can be picked up. The piece *n* prevents any one passing a wire up through *o* beyond *n*.

A push button *r* could be mounted on the slot device, so that the subscriber would have to press it and thus close the circuit at *s* when requested to do so by the operator and before she would give the connection desired. Better contact could be obtained at *s* than at *e*, but it would require the assistance of the subscriber. This push button could be used as an emergency device only, to be used only when the contact between *e f* refused to work properly.

11. The meter is connected to contact *1* instead of directly to line *l* because nickels frequently get stuck in the slot and cannot be deposited by the operator. As a result, when the operator attempts to ring the subscriber's bell, current would flow through the nickel and the meter, if the nickel were in the slot and the meter connected directly to the line side *l* of the circuit, instead of through the bell magnets. Moreover, if connected directly to side *l*, the line signal *L l* would be permanently displayed if a nickel were stuck in the slot. The magnet *c b* in the meter is adjusted to operate through 1,500 ohms and the source of current, in Chicago, is the Edison electric-light three-wire circuit, which gives +110 volts between one outside wire and the middle wire and −110 volts between the other outside wire and the

middle wire, which is permanently grounded at the power station where the direct-current generators G, G' are located. If G, G' are generators located in the telephone exchange, a relay with one winding could be connected between the generators and the ground g' in place of the double-wound relay shown in the figure.

The 110 volts has a tendency to charge all the condensers on a ten-party line, which will discharge either through the ringers or back to the line. A repeated pressing of the keys K, K' causes all the bells to strike, which is annoying to subscribers when they answer and are not wanted. Moreover, the discharges from a condenser charged with 110 volts back into the cable wires are apt to injure the insulation of the cable wires. Condensers are also frequently punctured by this discharge, which gives the operator a signal that she mistakes for a nickel sticking at the instrument that she answers, causing her to report the meter for repairs when the trouble is elsewhere. Plumbers, also, cause considerable trouble by breaking the ground wires attached to the pipes in the building; this causes the operator to tell the subscriber that he has not deposited the necessary nickel even if he has done so, which results in dissatisfaction on the part of the subscriber; furthermore, the repairman is apt to receive a severe scolding, which he does not deserve, when he goes to repair the instrument.

12. A somewhat different nickel-in-the-slot collecting device, also used by the Chicago Telephone Company, is shown in Fig. 8. The coin chutes x, w, z, i and x, w, y are formed by slots in a brass plate u. If a nickel A is deposited in the slot at x, it runs down the slot, strikes pin c, and falls into the position B, where it is held by the pins a, b, which are fastened to the armature of a magnet resembling that of an ordinary polarized ringer. These pins a, b project through holes in the brass plate u into the slot. Coins smaller than a nickel five-cent piece fall between the pins a, b, strike the edge k, are deflected to the left, fall out of the slot at i, and are returned to the subscriber. If a nickel is already in the

position *B*, a following nickel will pass over and to the left of

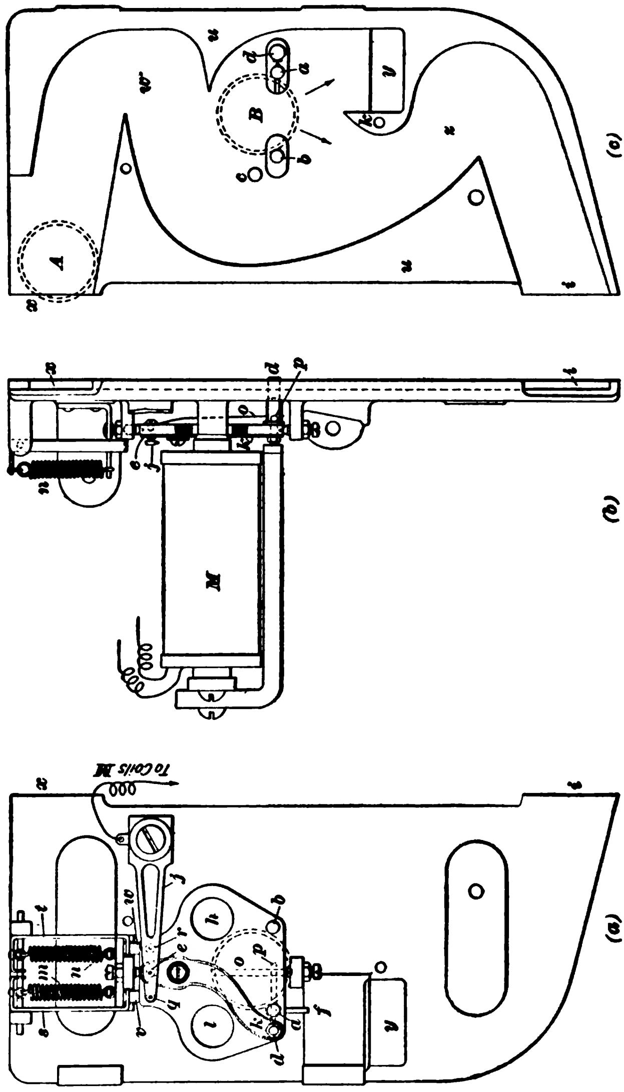


FIG. 8

pin *c* and be returned through the slot *i*. The weight of the nickel causes a slight movement of the pin *a*, thereby closing

a circuit between *a* and *d*, which are insulated from the armature of the electromagnet. On one side of the armature is a very thin spring *o* resting against a pin *p*; the spring tends to keep *a* separated from *d*. In the normal position of the armature, the contact spring *j* touches a contact pin *e*, which is connected by a thin insulated copper strip *k* with pin *d*, so that a circuit is closed from *j* through *e*–*k*–*d*–*a*–the nickel *B*–pin *b* to frame and ground. The spring *j* is connected through the coils *M* of the magnet to one of the line wires.

13. If the operator secures the connection desired, she presses one of two keys, which sends a current in such a direction through the magnet coils *M* that the armature is tilted enough to withdraw pin *a* from under the edge of the nickel and the nickel falls into the cash box *y*. If the connection desired cannot be obtained, she presses the other key, a current in the reverse direction flows through the coils, the pin *b* is withdrawn from under the nickel, which therefore falls to the left and rolls out of the slot *i* and is returned to the subscriber. In the armature are two holes *h*, *l*, into which the conical pole pieces project so as to give a uniform pull on the armature for quite a large movement. The springs *m*, *n* acting on the levers *s*, *t*, which in turn rest on the pins *v*, *w* projecting from the armature, tend to keep the armature in its middle position, with *j* touching *e*. When the armature is tilted, *j* parts from *e*, but touches either *q* or *r*, which are platinum rivets in the iron armature, and hence the armature will be held in a tilted position, irrespective of the variable contact through the nickel as it moves, until the operator releases her key. This device is used and connected on the ten-party-line circuits in the same manner as the one previously described.

NON-ELECTRICAL METERS

14. Gray Meter.—Purely mechanical coin-collecting devices used by the Bell and independent companies are made by The Gray Telephone Pay-Station Company. The mechanism of one size is shown in Fig. 9. There are no

electrical connections or moving parts. The plate forming the slots and supporting the gongs and the cash box is enclosed in a case that may be screwed to almost any part of the telephone cabinet that supports the transmitter.

The subscriber first removes the receiver, if the desired connection is obtained; the operator states the proper amount to be deposited. She can tell whether the proper amount is deposited by the sound transmitted through the telephone.

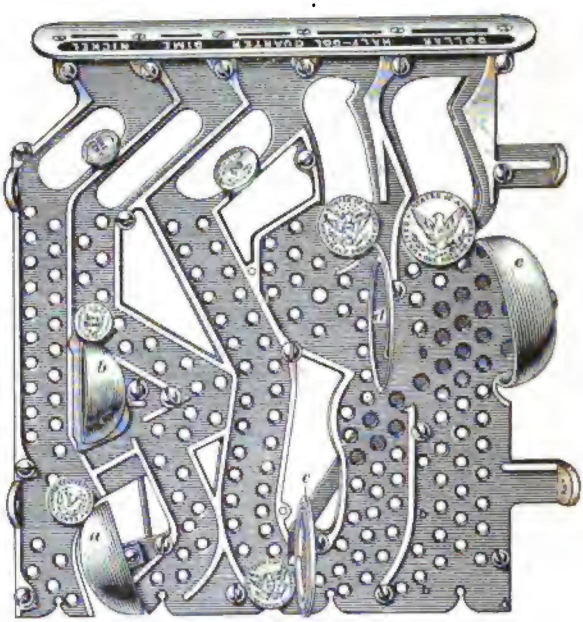


FIG. 9

The ring of a single bell is produced by a nickel striking the gong *a*, a dime strikes two gongs *b*, *a*, a quarter strikes one clock gong *c*, a half-dollar strikes two clock gongs *d*, *c*, and a dollar strikes a deep bell *e* and also produces a rattle. All the Gray coin-collecting devices, whether large or small, have this code of signals. The slots are of such size that coins larger than the denomination stated opposite a slot cannot be inserted and smaller coins, if inserted, fall out sidewise,

as shown where a one-cent piece is falling out of the nickel slot and a two-cent piece out of the quarter slot.

15. Measured Service.—While there are several forms of measured service, there is none that entirely fills the requirements. Automatic apparatus, either at the telephone or in the exchange, is not entirely satisfactory, for in case the line called for should be busy, some devices would, nevertheless, register the call without giving the required service. If either a meter or slot machine be placed at the telephone, it slows the service, for the operator must remain on the line until the called-for party is secured and the calling party has registered or deposited the required coin. This also works a hardship on the party called for, as it is necessary to wait until the party calling deposits the coin or registers. The system of measured service, where a meter is used at the subscriber's station, is also more expensive, inasmuch as it requires a visit to each telephone to take the reading of the meter before the bill for service can be rendered or to collect the money in the cash boxes. The system in use in a number of the largest Bell exchanges, and the one that some consider to give the best general results, is to have the operator mark down on a ticket the number of the telephone of each party calling, and in case the call is not completed to draw a line through that number. These tickets or sheets containing the record of the calls are collected every hour and sent to the bookkeeping department. Measured service handled in this way gives the subscriber a very prompt and efficient service. This class of measured service, in connection with four-party lines, will give excellent results. Handled in this way, the report "line busy" will be no more frequent than it is in the individual unlimited service; in fact, the calls will probably average less per four-party line than with unlimited individual lines. However, coin-collecting meters avoid the keeping and collection of accounts and their use is rapidly increasing.

ONE-RELAY SYSTEMS

WESTERN ELECTRIC NO. 8 SYSTEM

16. In the standard Bell central-energy system for large exchanges, there are two relays for each line circuit, and at least two relays in each cord circuit; moreover, considerable current is required to hold the cut-off relays closed during a conversation, and the supervisory circuit requires even more current while the supervisory lamp is extinguished during the conversation than when burning. For these and minor reasons, there has been devised a common-battery multiple switchboard for exchanges of 500 to 2,000 lines that requires only one relay for each line circuit and consumes less current. It is known as the **Bell, or Western Electric Company's No. 8 switchboard circuit.**

17. The **line circuit** is shown in Fig. 10. The line relay LR has two equal 500-ohm windings; in series with both windings is connected a 36-volt battery, the whole combination being permanently bridged across the line. There is, consequently, always a battery and 1,000 ohms bridged across the line. The springs w of all answering jacks at one operator's position are connected together before passing through the line-pilot relay a, and the wires from all the line-pilot relays on the switchboard are connected together before passing through the night-alarm relay c to the ground. When the subscriber takes down his receiver, sufficient current flows through the line relay to cause it to attract its armature, thereby allowing current to flow from the battery through a resistance d of 120 ohms–a 24-volt line lamp L–contacts in all jacks on that line–line-pilot relay a–night-alarm relay c–ground to battery and light the line lamp L. The subscriber's transmitter receives current

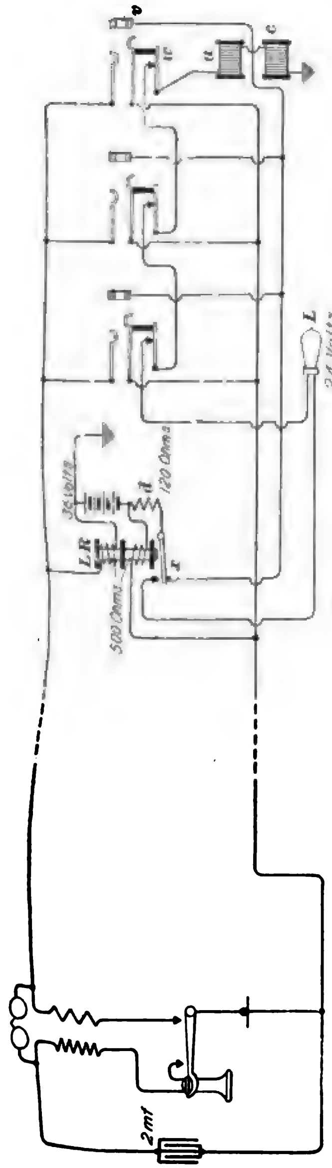

v
w
a
c
L
24 Volts
36 Volts
d
120 Ohms
LR
r
500 Ohms
2 mf

FIG. 10

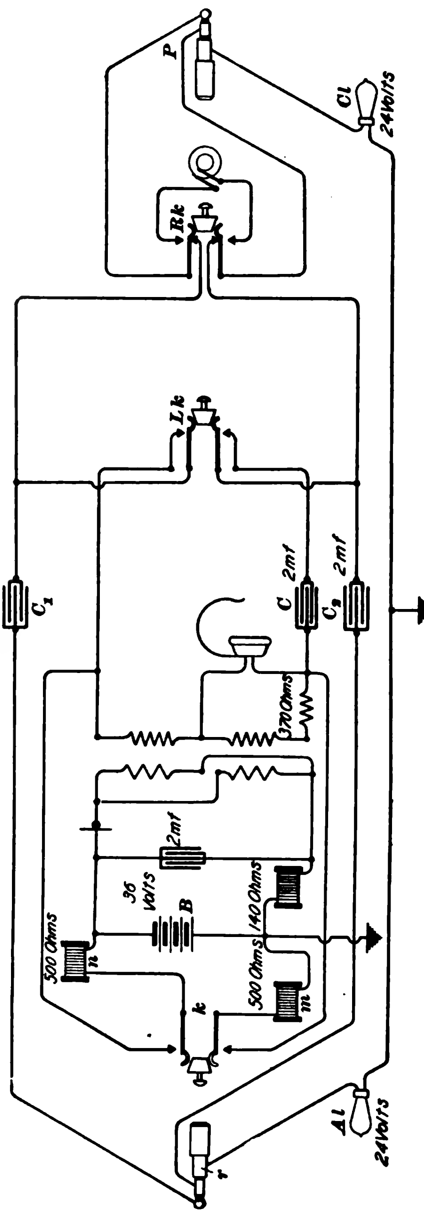

P
Cl
24 Volts
Rk
Lk
2 mf
C1
C 2 mf
C2 2 mf
370 Ohms
2 mf
36 Volts
B
140 Ohms
500 Ohms
n
500 Ohms
m
k
AL
24 Volts
r

FIG. 11

through the two windings of the line relay, and through no other source.

If a plug is inserted in any jack, the circuit containing the line lamp is opened in the jack itself, requiring, therefore, no cut-off relay. For a very large and long switchboard, the cost of the extra jack springs, their platinum contacts, and the extra wire will probably be greater than the cost of a cut-off relay.

18. The **cord circuit** is shown in Fig. 11. There are no relays in this cord circuit, and outside of the operator's transmitter and listening circuits not even a retardation coil. There are two condensers C_1, C_2 tightly compressed in small tin boxes, about 3 inches long by $1\frac{1}{4}$ inches square, and mounted in the framework of the switchboard and connected in each talking circuit. The insertion of an answering plug in a jack connects the supervisory lamp *A l* from ground through the plug ring *r*–jack-ring *v*, Fig. 10–contact *x*–resistance *d* to battery. When the subscriber's receiver is off the hook, the relay contact *x* is open and hence a supervisory lamp can be lighted only when the subscriber hangs up his receiver.

After closing the listening key *L k*, the operator can converse with the subscriber, an anti-side-tone operator's circuit being provided for this purpose. If the operator, on account of a doubt as to the progress of a conversation, should find it necessary to listen in on a conversation, the electrical conditions would be disturbed by closing and opening an ordinary listening key, like that shown at *L k*, because the condenser *C* will instantly absorb a charge when the key is closed and discharge when the key is opened, thereby producing a click the moment the listening key is closed or opened. To avoid this, there is provided a key *k* that serves to connect two 500-ohm retardation coils *m*, *n* and the battery *B* across the operator's listening circuit before the listening circuit is connected across the cord circuit and to disconnect them from the listening circuit after the latter is disconnected from the cord circuit. Thus the condenser

is held at the same potential as the cord circuit while it is being connected to or disconnected from it, and hence no clicks are produced in either case in the subscriber's receiver. In actual practice, the key *k* is made a part of the listening key *L k*, but it is shown separately here to make the figure clearer.

19. The **busy test** is made, as usual, with the tip of the calling plug *P*. If the called line is not busy, no click will be produced, because both the tested bushing and the tip of the plug *P* are at the full potential of the battery since no current is flowing in either circuit. If the called subscriber is also calling, but has not yet been answered, the line relay will have attracted its armature and hence the tested bushing will be on open circuit and no click will be produced and consequently a connection can be completed.

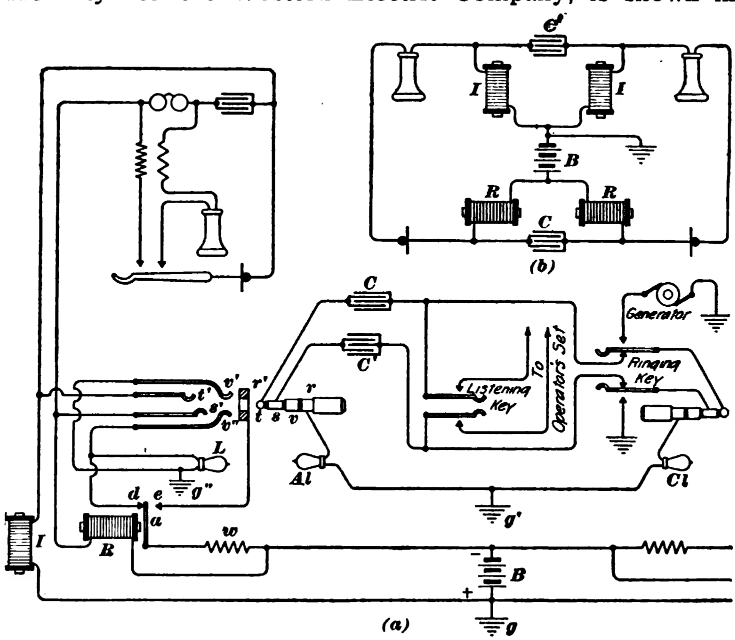
If the line is busy, the jack bushing *v* is connected through a supervisory lamp to ground and hence is not at the full potential of the battery, while the testing tip is at the full potential of the battery. Consequently, a busy-test click will be produced. When the called subscriber answers, his transmitter receives current through its own line relay.

20. Notwithstanding the insertion of 1,000 ohms resistance between the battery and line, the transmission is good over all but very long lines. For long toll lines, special cords containing repeating coils are used, so that ample current for a louder transmission is supplied. A 36-volt battery is used in place of the 24-volt battery generally used in the larger common-battery exchanges of the Bell Company. Transmitters of standard design are used; in fact, the subscriber's telephone departs in no way from the regular equipment. It is, indeed, a question whether the articulation with such high-resistance relays is not slightly more pleasing than with standard conditions used for larger switchboards; and there is, without doubt, a very agreeable absence of deafening clicks to annoy the subscriber. Condensers in the talking, or cord, circuit do not act harmfully on conversations between local subscribers; indeed, the accepted practice of

the Bell Company in toll switchboards involves the use of condensers in just this way, so that there are at least four condensers of two microfarads each in every connection between two common-battery subscribers in different cities. Even when several sets of condensers, of two microfarads capacity each, are involved in building up a connection, the character of speech does not seem to suffer, and expert listeners sometimes detect an improvement of articulation while the influence of repeating coils is distinctly to impair articulation.

McBERTY ONE-RELAY SYSTEM

21. A one-relay central-energy system, devised by F. R. McBerty for the Western Electric Company, is shown in



(a)

FIG. 12

Fig. 12 (*a*). It is not a multiple-switchboard system, but one could perhaps be developed from it. In this arrangement, the line relay *R* does all the work of regulating the

operation of both line and supervisory signals. I is an impedance coil used to balance the line relay R. The jack has two extra contacts v', v'', which are connected together, when a plug is inserted in the jack, by the insulated metal ring v on the plug.

When the subscriber's receiver is removed from its hook, current flows from the central-office battery B through the impedance coil I, line and relay R, thus causing the relay to attract its armature a, thereby allowing sufficient current to flow through B–g–g''–L–d–a–resistance w to light the line lamp L. When the operator inserts a plug in the jack, t connects with t', s with s', r with r', and the ring v connects v' to v'', thus short-circuiting the line lamp L, the resistance w being large enough to prevent the use of an unreasonable amount of current when L is thus short-circuited. Since the ring circuit is open at e, the supervisory lamp $A\,l$ does not light. During conversation, the transmission circuit, stripped of unnecessary details, is shown in Fig. 12 (b), from which it will be seen that a very evenly balanced circuit is obtained. The subscribers' transmitters, which, for the sake of simplicity, are shown here in series with the receivers, are supplied with current from B through the relays R and the impedance coils I, the two circuits being connected together through the condensers C, C'.

When the subscriber hangs up the receiver, the relay R releases its armature and consequently sufficient current can now flow through B–g–g'–$A\,l$–r–r'–e–a–w–B to light the supervisory lamp $A\,l$. When the plug is withdrawn from the jack, $A\,l$ goes out and all circuits return to their normal condition.

SPECIAL CIRCUITS

22. Elimination of Disagreeable Noises.—In most central-energy systems, very disagreeable noises are produced in the waiting subscriber's receiver when the connections are being made. To eliminate the noise due to the static discharge of the called line and its apparatus, after the ringing generator has been used, A. B. Stetson has devised the arrangement shown in Fig. 13, for the Bell central-energy system.

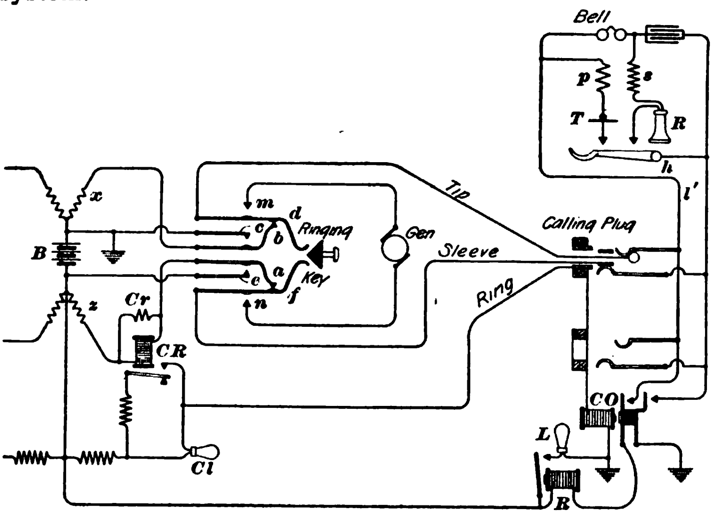


FIG. 13

When an ordinary ringing key is released, there is usually an explosive sound, audible to the waiting subscriber, due to the discharge of the called subscriber's line through one side of the repeating coil in the cord circuit. The simple means adopted in this arrangement to prevent this noise consists only in establishing a short circuit around the repeating-coil windings as the ringing key is released. As shown in

this figure, the ringing key is provided with an extra pair of springs *c*, *e* adapted to make contact with *b*, *a* before the latter part from *d*, *f*, respectively. When the ringing key is fully closed, *d* touches *m*, *f* touches *n*, *c* touches *b*, and *e* touches *a*. As the key is released, the springs *d*, *f* first part from *m*, *n*, respectively, and an instant later, when *d* touches *b* and *f* touches *a*, the line discharges through *d*–*b*–*c*–*B*–*e*–*a*–*f*, which short-circuits the windings *x*, *z* of the repeating coil. This circuit remains closed long enough to allow the line to entirely discharge, and thus prevents the discharge from passing through the windings *x*, *z*. When the key reaches its normal position, as shown in the figure, contacts *c*, *e* no longer touch the springs *b*, *a* and the line circuit is closed between *d*, *b* and *f*, *a* only.

23. Modification of Subscriber's Circuit.—In Fig. 13 is also shown a slight modification, patented in 1903 by A. B. Stetson, of the regular subscriber's circuit used by the Bell Company. The modification consists in connecting the transmitter *T* between the primary winding *p* of the induction coil and a contact of the hook switch instead of between the hook switch *h* and the line *l*, as heretofore shown. The older arrangement is very efficient, but it is said to cause considerable side tone due to a double effect of the local transmitter on the local receiver. A change in current strength due to the transmitter *T* is produced, as with the older arrangement, directly in the line circuit *l*–*h*–*T*–*p*–*l'*, but this change affects the local receiver *R* only by induction through the induction coil. With this arrangement, the subscriber's receiver, secondary winding, and condenser practically form an almost independent local circuit, the wire *h*, *l* merely serving as a common portion of both the line and local circuits.

In the older arrangement, the local transmitter caused a variation of potential between the points *h* and *l* that had a direct effect on the local receiver. The arrangement shown here is claimed to reduce the side tone without reducing the efficiency. This arrangement is not advantageous for

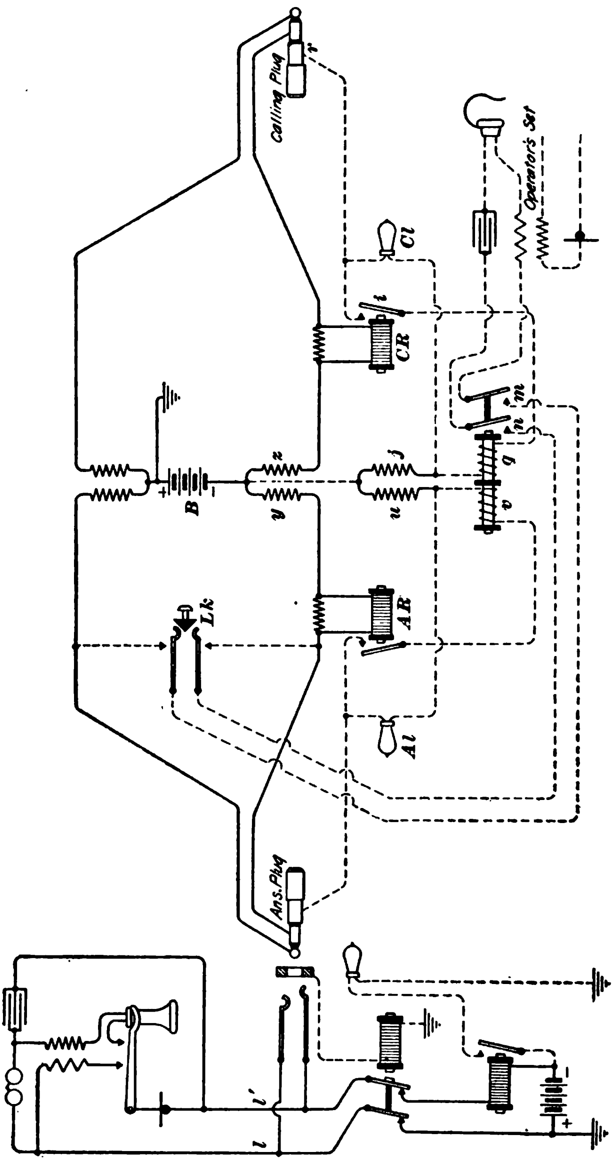


Fig. 14

long line circuits, but may be used where the subscriber objects to the side tone due to the abnormally large current received on account of the instrument being near the exchange. The resistance of p is about 17 ohms, s about 27 ohms, and R 80 ohms.

24. Secrecy Arrangement.—Many telephone users hesitate about mentioning confidential matters over the telephone, because of the fear that the operators will overhear them. To eliminate this objection, where necessary, the **secrecy arrangement,** shown in Fig. 14, has been devised by E. H. Smythe for the Western Electric Company; it is adapted to the Bell central-energy system. The operator's set is connected through the contacts m, n of a differential relay to the usual listening key $L\,k$; this circuit is closed only when the differential relay is energized, which is the case when current flows through only one winding, v or q, of the differential relay.

When the operator answers a call by inserting the answering plug in a jack, the supervisory relay $A\,R$ is energized by the current that flows through the subscriber's transmitter, thereby connecting v in parallel with the answering supervisory lamp $A\,l$, which allows sufficient current to flow through v to energize the relay (no current can now flow through q, for the circuit is open at both r and i), thereby closing at m, n the operator's listening circuit. Hence, by closing the listening key $L\,k$, the operator can communicate with the subscriber. When the operator inserts the calling plug in a jack and the called subscriber answers, current will flow through $C\,R$ and then through q, in such a direction as to neutralize the magnetizing effect of v, and consequently the differential relay releases its armature and the operator cannot listen in while the two subscribers are conversing. But, as soon as either subscriber hangs up his receiver, only one of the windings v or q will receive current, which will cause the differential relay to be energized. When both subscribers hang up their receivers, there will be no current in either winding v or q. Thus the differential relay does not attract

its armature and hence keeps the listening circuit open when both receivers are hung up, both receivers off their hooks, or both plugs withdrawn from the jacks, but does attract its armature when one receiver only is off the hook and one or both plugs are in the jacks.

25. Supervisor's Lamp.—Several interesting features introduced, in 1903, in a new exchange of the Chicago Telephone Company are worthy of brief notice here; among them is the arrangement of the **supervisor's lamp.** Each operator has a locking key placed in the panel of the board in front of her, which she locks when she wishes to communicate with her supervisor. The locking of this key closes a relay and lights a small lamp placed at the top of the board at her position which, in turn, starts a buzzer located in the center of her supervisor's division. The supervisor, hearing the buzzer, looks for the lamp and responds to that operator's call. If it is a subscriber making a complaint, the supervisor connects her own breastplate set through an idle or second operator's jack at that position to the calling plug of the cord circuit in use and attends to the subscriber.

By a somewhat later arrangement, the operator simply inserts the calling plug into a certain jack in the multiple in front of her. This lights a supervisor's lamp in the upper part of the board, and the supervisor plugs into an operator's jack and converses with the operator in question. No disturbance is created by this method, which is now becoming standard practice with the Bell Company. There are two lamps for this purpose in each section covered by the same supervisor, and the buzzer is located behind the switchboard.

26. Overflow Positions.—Another feature consists of three **overflow positions** to equalize the load during busy hours, usually from 9 to 11 A. M. and from 6:30 to 8:30 P. M. A number of busy lines are selected in each position where the traffic is too heavy during these hours and they are connected by means of four jumpers (in the ring, tip, sleeve, and line-lamp circuits) on the vertical side of the intermediate

board, to the answering jacks of a position previously selected for the overflows. The relays in the overflow positions are disconnected and the relays belonging to each transferred line cause a line lamp to light at both the regular and the overflow positions. The two line lamps are thus operated in parallel. In the regular position, a line so transferred to the overflow position has its lamp covered with a blue opal. When the overflow position is put in service, the supervisor tells the operators not to answer those lines until she is later notified that the overflow positions are to be taken out of service. It is claimed that this reduces the cost of operating, by giving each operator about all the lines she can properly attend to during hours that she would otherwise not be very busy.

27. Hospital Position.—Another plan introduced in the same exchange provides for one position equipped for out-of-order, or so-called sick, lines. This is located on the subscriber board and is known as the **hospital position.** An operator, on finding that a line is out of order, notifies over an order wire a hospital operator, who has access to multiple jacks bridged on each trunk and subscriber's line. The hospital operator picks it up in the multiple by one of her cords, the shank of which is connected with a mild howler that superimposes an interrupted current on the battery current. This pulls up the subscriber's cut-off relay and puts a well-recognized light musical noise on the shank of all jacks on the same line, which is known among the operators as the hospital tone test. The hospital operator then makes a note of the case on a form especially provided for her use, showing the line that is up, the time put up, and the time referred to the repair department. She then refers the trouble to the trouble desk over a call circuit. Subscriber and trunk operators, on getting this tone test on any line, connect the calling party to local trunks, which are multiplied throughout the subscriber and trunk boards and terminate in lamps and jacks in front of the hospital operator. The hospital operator, in answering calls over these local trunks, uses the

phrase, "What number are you calling, please." On receiving the calling party's order, she attempts to raise the desired party, whose line is out of order. Quite a few connections are completed in this manner. But if she is unable to do so, she tells the calling party that the line is out of order.

28. Instrument and Line Complaints.—Each operator's position for handling local calls is equipped with a special pair of cords, which are used to connect subscribers complaining of trouble on their line or instruments direct to a trouble desk. It is thus possible to give immediate attention to all complaints, and the line and instruments, furthermore, are tested with the person making the complaint. This is a most satisfactory arrangement.

29. Information Position.—This exchange is also equipped with one **information position.** The operator in this position, having access to all multiple jacks, looks up any information that subscribers may wish to obtain. For a telephone that has been taken out, but whose name and number appears in the current issue of the directory, the multiple is plugged with a red cork; a dead line or telephone taken out, and whose number does not even appear in the current issue of the telephone directory, the multiple is plugged with a black cork; a line on which the calls are being questioned for any cause, the multiple is plugged with a green cork; a number changed to a different exchange, the multiple is plugged with a cork on which appears the new exchange and number. Operators getting a call for any of the above, connect the calling party with the information operator, over local trunks, which are multiplied throughout the subscriber and trunk boards, and terminate in lamps and jacks in front of the information operator. The subscriber operators send all calls for persons by name or question calls of any character, to the information operator.

BELL TRUNK CIRCUITS

TRUNK CIRCUITS

INTRODUCTION

1. The method of handling calls between two exchanges will now be considered. If party *A* in exchange district No. *1* wishes to communicate with party *B* in exchange district No. *2*, he will first call the operator in his own exchange. Having received the call, she will communicate with exchange No. *2* in some way and assist in establishing a circuit between the two exchanges. An operator at exchange No. *2* will then complete the connection between the circuit just established and the line of subscriber *B*. Circuits running between exchanges, and used to complete the connection between two subscribers' lines, are called **trunk circuits,** or more shortly, **trunks.**

2. Classification of Trunk Circuits.—There are three classes of trunk circuits in general use between exchanges: first, the **circuit trunk,** which terminates in a jack at the sending end and is equipped with a plug and an automatic disconnect signal at the receiving end; second, the **ring-down trunk,** which consists of a jack at the sending end and a jack and drop at the receiving end; and third, the **common trunk** or **two-way trunk,** which is used for connections originating at either office and is equipped with a jack and drop at both ends of the line. The first two can be used to transmit calls in one direction only, while the common trunk can be used to transmit calls in either direction.

Circuit trunks take their name from the fact that they are used in connection with a special circuit, called an **order wire,** which is used solely to transmit information between operators at the two exchanges. Ring-down and common trunks can be used between exchanges independently of the nature of their switchboard equipment; but circuit trunks must be arranged to suit the switchboard circuits with which they are used.

3. In the modern central-energy switchboard, the use of common trunks is kept as low as possible, as they require that one position be equipped as a common-trunk answering position; and, in addition, the jacks must be multipled throughout the board for the use of the subscriber operators, the trunk signals appearing only at the common-trunk position. The ring-down trunks are, in like manner, multipled throughout the switchboard for similar purposes, while the receiving trunks of this class appear with other signals at a receiving-trunk position. It is, of course, desirable, in cases where the number of ring-down and common trunks is not too great, to terminate them with other signals at one position so that they may all be handled by the same operator. The outgoing trunks are multipled throughout the switchboard before the subscriber operators, while the incoming trunks, which terminate in a cord and plug, are located at separate trunk positions, the usual number being from twenty-eight to thirty-two trunks per position. The outgoing trunk of one office is evidently the incoming trunk of the other office, and vice versa. The question as to which of the three classes of trunks shall be used between offices depends on the volume of the traffic; it is usually considered that seventy-five calls per day each way warrant the use of circuit trunks. The efficiency of ring-down trunks is about two-thirds of that of circuit trunks, while common trunks are still less efficient.

It is usual to assume that an operator at a central-energy switchboard with automatic calling and disconnect signals can handle and complete from 1,600 to 1,800 flat-rate calls

in the course of 24 hours, the greater number of these calls being handled during the three or four busiest hours. An operator at the same kind of a switchboard can handle about 800 message-rate calls per day, although, if the length of the message must also be kept track of, she cannot handle so many. About 500 pay-station calls, which involve the extra labor of timing and supervison, can be handled per day by the average operator.

4. Ring-Down Trunks.—In using a ring-down trunk, the operator in the exchange where the call originates inserts the calling cord in the trunk jack and depresses the ringing key, thus throwing the drop at the distant office. The operator at the distant office, on noticing the drop fall, introduces the answering plug of one of her cord circuits into the trunk jack, and learns from the operator at the originating office the number desired. She proceeds to get the number in the usual manner, the connection being established between the called-subscriber line and the trunk through the cord circuit in exactly the same manner as it is between the calling-subscriber line and the trunk. Ring-down trunks are used between exchanges equipped with multiple switchboards when the amount of trunking business is light; for under these conditions they answer the purpose very well. When so used, they are equipped at the incoming end with an answering jack in addition to the drop; and the calls sent over them are received by an operator set aside for this purpose. At the outgoing end, they are equipped with multiple jacks only.

5. Common Trunks.—When common trunks are used between exchanges equipped with standard boards, they are equipped with a drop at each end. If the number of sections in each office exceeds three, the trunks are usually multipled through every alternate section; otherwise, they terminate before the middle operator. When this class of trunk is used between offices equipped with multiple switchboards, it terminates at each office, in addition to the multiple jacks, in an answering jack and drop. The method of using a

common trunk is the same as that described for the ring-down trunk, with the additional provision that calls can be transmitted either way.

6. **Circuit trunks** can be used to transmit calls in one direction only and terminate at the incoming end in cords and plugs, one cord and plug for each trunk; at the sending end, they are equipped with multiple jacks only. The method of operating these circuits is as follows: The subscriber operator at the exchange in which the call originates, on learning the number required, connects herself with the incoming-trunk operator at the required office by depressing an order-wire key and repeats the number called for. The incoming-trunk operator, having thus received the call, takes up one of the unused circuit trunks from the originating office and calls back to the originating operator the number of the trunk so taken up. She then tests the multiple jack connected to the line desired, to ascertain whether or not it is in use. If the line is idle, the trunk plug is inserted in the jack and the subscriber rung up in the usual manner. The operator at the originating office, on hearing the trunk number called back, inserts the calling plug in the corresponding trunk jack and listens in. A circuit is now established between the calling-subscriber's line and the trunk at the originating office through the cord circuit, and at the incoming office between the trunk and the called-subscriber line, through the trunk cord and plug. When the called subscriber answers, he is heard by the operator at the originating office, and the conversation is allowed to proceed. On completion of the conversation, the parties ring off, throwing the clearing-out drop before the originating operator, who takes down the connection and, going in again on the order wire, directs the trunk operator to withdraw the trunk plug from the called-subscriber's line jack, thus clearing the trunk.

7. For example, let it be supposed that subscriber number 700, whose line terminates in the Cortlandt Street exchange, New York City, wishes to talk with subscriber number 49, whose line terminates in the Harlem exchange,

New York City. The party at 700 Cortlandt, having called the operator in the usual way, would say to her "give me number 49 Harlem." The Cortlandt operator will then go in on the Harlem order wire and say "number 49 for Cortlandt." Supposing that the number of an unused trunk is 5, the Harlem trunk operator will then call back over the circuit "take it on number 5" and proceed to call the desired subscriber. The subscriber operator at the Cortlandt office will then introduce the plug of the calling cord into the multiple trunk jack number 5, thus completing the connection. When the conversation is completed, the originating operator will again go in on the order wire and say "clear 5 to Cortlandt" which the trunk operator will do by withdrawing the trunk plug from jack 49.

Should the line called for be in use, the trunk operator will introduce the trunk plug into a special jack, called the *busy-back jack*, which is connected to a circuit carrying an interrupted current and produces a tone test that is heard by the originating operator when she plugs into the trunk jack to complete the connection. In this case, she will tell the calling subscriber that "the line is busy."

8. The operators sitting in front of sections where the subscribers' lines terminate in answering jacks and line signals and the trunks terminate, usually in jacks, are called *subscriber operators*, or *A operators*, while operators sitting before sections where the incoming trunk lines terminate, usually in plugs, are called *trunk*, or *B*, *operators*, and the positions are designated in the same manner. The magneto-trunk circuits used by the Bell Companies will be explained first.

MAGNETO-TRUNK CIRCUITS

TRUNK BETWEEN SERIES-MAGNETO-SWITCHBOARDS

9. In order to lessen the work required to complete and clear a connection over a circuit trunk, and thereby increase its efficiency, several ingenious arrangements have been developed. Fig. 1 shows the simplest form of a circuit trunk between two exchanges equipped with series-multiple magneto-switchboards, in which the multiple jacks at the sending

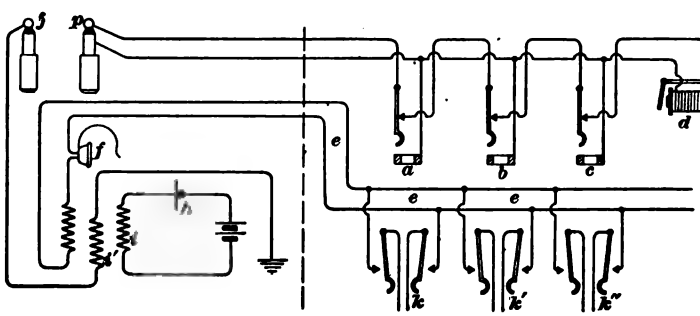


FIG. 1

office are shown at *a*, *b*, *c*, the order-wire circuit is shown at *e*, and the order-wire keys at the sending office are shown at *k*, *k'*, *k''*. The order-wire circuit ends at the incoming-trunk operator's receiver *f*. Her local primary circuit contains a transmitter *h* and one winding *i* of an induction coil that is provided with a third winding *i'*, to which is connected a single plug *j*, the other end of this winding *i'* being grounded. The incoming end of the trunk terminates in the plug *p*. The circuit containing the plug *j* and the grounded coil *i* is used to determine whether the required line is busy in the following manner: When a subscriber's line is in use, a battery is connected to the rings of all its jacks, so that the trunk operator, by touching the tip of the plug *j* to the ring of one of these jacks, allows current to flow therefrom through the coil *i'* to ground. This current produces, by

induction, a grating noise in the receiver *f*. If the required line is not in use, no battery will be connected to the rings of its jacks and the trunk operator will therefore hear no sound on touching any one of them with *j*.

After the trunk has passed through the multiple jacks, a **safety drop** *d* is connected to it to avoid putting the called subscriber's instrument out of service. Should the trunk, or *B*, operator, on the completion of the conversation and the consequent ringing off by the subscribers, fail to clear out after having been ordered to do so by the originating, or *A*, operator, the called subscriber will still have his line connected to the trunk after it has been disconnected from the calling-subscriber's line, and he will therefore have no means of signaling either of the exchanges. Therefore, the drop *d* is connected to the trunk in such a manner as to be cut off when the connection is completed at the originating office, and connected again when it is taken down. If, therefore, the trunk operator fails to clear out, the called subscriber, on ringing, throws the safety drop *d* at the originating office, thereby attracting the attention of the operator sitting before it. This operator thereupon goes in on the trunk, learns the wants of the subscriber, and, going in on the order-wire circuit, again directs the trunk operator to clear the connection.

TRUNKS BETWEEN BRANCH-TERMINAL SWITCHBOARDS

10. In order to put up a trunked connection, the trunk operator must do two things: first, touch the ring of the jack on the required line with the testing plug *j*; and second, insert the trunk plug *p* in the jack. This double motion results in a loss of time to the trunk operator, a reduction in the number of calls she is able to handle in a given time, and therefore a loss of efficiency in her operating. To overcome this, the trunk shown in Fig. 2 was devised for use between branch-terminal multiple switchboards. It can, however, be adapted for use with the series-multiple switchboards. Here, as before, the order-wire circuit is shown at *e*, the order-wire keys at the originating office at k, k', k'', and the multiple

trunk jacks at *a*, *b*, and *c*; while the incoming-trunk plug is shown at *p*. The feature of this trunk is the key *X*, to the outer contact *d* of which is wired one side of the trunk; the spring *y* is connected to the tip of the trunk plug, while the inner contact is wired through the coil *i'* to ground. The trunk operator, on receiving the request for a number, merely touches the tip of the trunk plug to the ring of a jack wired like jacks *a*, *b*, *c*. If the desired subscriber's line is busy it is due to a plug in the subscriber's jack that connects

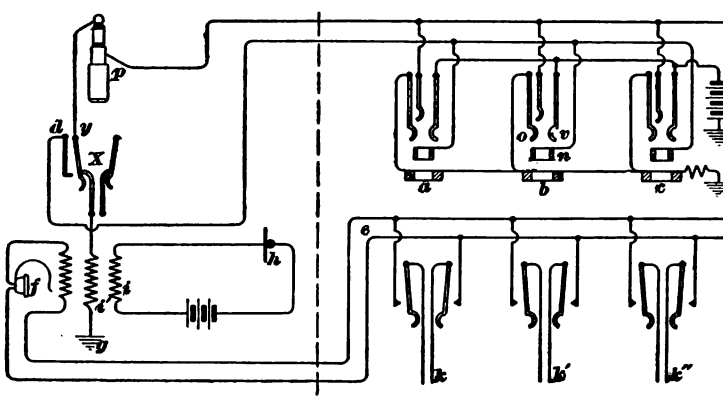


FIG. 2

together springs like *o*, *v*, thereby connecting the battery to the outside rings, like *a*, *b*, *c*, of all jacks of the subscriber's line. If the jack is on a busy line, current will flow from the ring through the tip of the plug and the winding *i'* to ground, thus giving the operator the required test. If the trunk operator does not find the line in use, she inserts the plug in the jack and operates the key *X* so that contact is broken with the inner point and made with the outer spring *d*, thereby cutting off the test coil *i'* and rendering the trunk ready for conversation.

While the operation required to put up a connection with this trunk is shorter than that explained by the aid of Fig. 1, it requires, besides the introducing of the trunk plug into the required subscriber's jack, the manipulating of the key *X*.

The next arrangement developed did away with the manipulating of this instrument.

11. In Fig. 3 is shown the incoming end of a circuit trunk; all parts not shown are identical with those shown in Fig. 2. The middle contact of the trunk plug *p*, which in Fig. 2 was a solid brass collar without a connection and served only to connect the two springs of the jack, thereby throwing on the busy test, has in Fig. 3 a connection that runs to a relay *W*, the other side of which is connected to ground *g*. The armature of this relay is connected to the tip of the plug while the outer contact is wired to the coil *i*; the other side of the trunk is wired to the inner contact *u* of the relay. On receiving the order for a connection, the trunk operator makes the busy test by merely touching the tip of the plug to the ring of the desired jack, the busy-test circuit

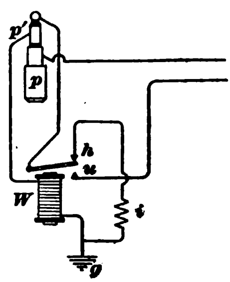


FIG. 3

being completed through the armature of the relay–outer contact *h*–coil *i*–ground. On introducing the plug into the subscriber's jack, the restoring battery on the jack is connected to the middle contact of the plug, thence through the relay *W* to ground. The relay thereupon becomes energized and cuts off the testing circuit through *i*, and cuts in the other side of the trunk through *u*, thus completing the circuit of the trunk for conversation. This operation is altogether automatic and requires no further action on the part of the trunk operator than the mere introduction of the trunk plug into the required subscriber's jack. The time wasted in manipulating the key *X*, Fig. 2, is therefore saved.

12. The changes in the design of a circuit trunk so far described have been solely in the direction of reducing the time necessary to put up a connection, but there still remains two defects to be overcome: The first, to insure the disconnection of a trunk on the completion of a conversation; the second, to make it unnecessary for the originating operator

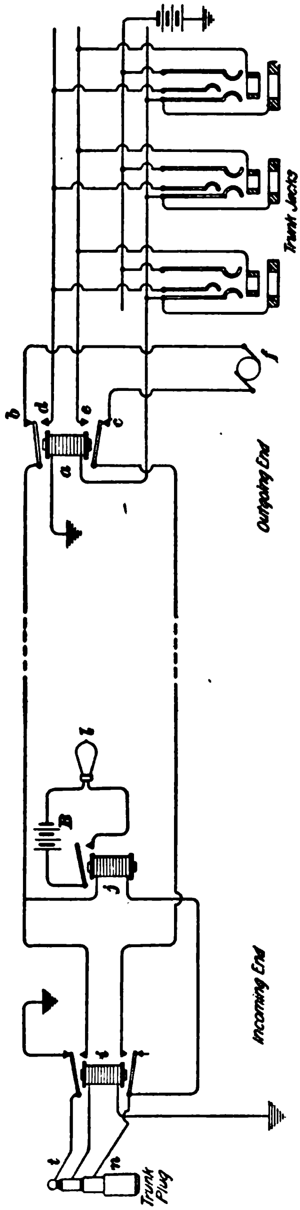


FIG. 4

to go in on the order-wire circuit to order the clearing of the connection, which is necessary with any of the trunk circuits already described. Using the circuit for clearing out delays other calls and thus reduces the efficiency of the trunk and the order wire. Also the failure of a trunk operator to promptly clear a trunk on the completion of the conversation results in that trunk being kept out of service during the time that it is so held up, thereby causing a second reduction in the efficiency of the trunk. It is, therefore, of the utmost importance that a trunk should be put into or released from service with the least possible delay. To this end the following system of automatic disconnecting signals has been devised.

The trunk shown in Fig. 4 is typical of the trunk circuits connecting two branch-terminal offices. At the outgoing office is placed a relay *a* that has its 45-ohm coil connected to the busy-test springs on the jacks. To the outer contacts *c*, *b* is wired a direct-current generator *f* delivering a current at a potential of 75 volts; to the inner contacts *d*, *e* are wired the two sides of the talking circuit. At the incoming end, there is,

in addition to the 45-ohm relay *i* for cutting off the test, a second relay *j*, both of which are actuated when the trunk plug is introduced into a subscriber's jack. The relay *j* is so constructed that while it responds to a direct current it is altogether irresponsive to an alternating ringing, or talking, current.

13. Controlled by the relay *j* is a circuit carrying a lamp *l* and a battery *B*. The action of this circuit is as follows: The trunk operator, on introducing the trunk plug into the called-subscriber's jack, energizes the relay *i*, thus bridging the relay *j* across the trunk wires *t*, *n*. Assuming that the subscriber operator at the outgoing end has not yet taken up the trunk, that is, has not yet inserted her calling plug in the trunk jack before her, the relay *a* is not energized and consequently the direct-current dynamo *f* is applied to the trunk line *t*, *n* through the contacts *b* and *c*. As a result, the relay *j* is energized and the circuit carrying the lamp *l* is closed and the lamp therefore lighted. When the subscriber operator takes up the trunk, that is, inserts a plug in one of the trunk jacks at the outgoing end, the relay *a* becomes energized, the contacts at *b* and *c* broken and those at *d* and *e* made, with the result that the current from the dynamo *f* is cut off the line and the talking circuit cut through.

When the current from the dynamo is cut off, the relay *j* will cease to be energized, the lamp circuit broken, and the light *l* put out. On completion of the conversation and consequent removal of the calling plug from the trunk jack by the subscriber operator, the relay *a* ceases to be energized, with the result that the talking circuit is broken and the current from the dynamo *f* again thrown on the line. Consequently the relay *j* on the incoming end again becomes energized, its lamp circuit closed, and the lamp *l* lighted. The lighting of this lamp informs the trunk operator that the trunk has been cleared at the originating end, and she, therefore, clears her end, without waiting for further instructions. This arrangement makes it unnecessary for the subscriber operator to go in on the order wire to order the trunk cleared,

thus saving her own time and reducing the use of the order wire, while an automatic signal lamp *l* notifies the trunk operator the instant the trunk is out of use.

COMMON-BATTERY TRUNKS

14. The circuit shown in Fig. 4 represents, as far as the previously mentioned features are concerned, the highest development of a circuit trunk for use with magneto-switchboards. With the introduction of central-energy systems, additional signals have been placed before the incoming-trunk operator. One, called the **ringing lamp,** is used to inform the trunk operator of the instant that the receiver has been removed from the called subscriber's hook; another, called the **B disconnect signal,** lights when the called subscriber hangs up the receiver on the completion of the conversation. In order, however, to discuss the nature and the method of operation of these two signals, it is necessary to consider the subject of common-battery circuit trunks in detail.

15. Common-battery trunks are divided into two classes: Those between offices, one of which is equipped with a central-energy switchboard and the other equipped with a magneto-switchboard; and those between offices having complete central-energy equipments. The first condition prevails in cities during the time of transition from the magneto to the central-energy systems, or in territories in which some of the exchanges are not of sufficient size to warrant the installation of the central-energy system; the second condition prevails where all exchanges having circuit-trunk intercommunication are equipped with central-energy switchboards; as, for example, in the Borough of Manhattan, New York.

TRUNK FROM CENTRAL-ENERGY TO MAGNETO-SWITCHBOARD

16. In Fig. 5 is shown a trunk from a central-energy switchboard to a magneto-switchboard of either the series or bridging multiple types. At the outgoing end, in the

central-energy office, the rings of the multiple jacks are wired through the coil of a relay *R* to ground *g*. Each movable spring on this relay is connected to an inner terminal of one winding *a* of a repeating coil. The winding *b* is connected to the sleeve and tip contacts of the jacks.

At the incoming end, in the magneto-office, the trunk terminates in the winding *c* of a second repeating coil. The middle point of this winding is connected to the coil of a magnetic signal *d* whose other terminal is connected through a battery *B* of 24 volts to ground. The battery *B* could also

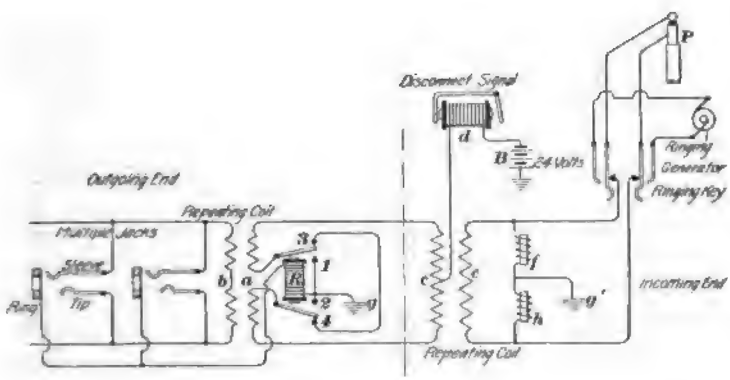


FIG. 5

be placed between contacts *1*, *2* and the ground *g*. The primary winding *e* of the repeating coil is wired through the contacts of the ringing key to the tip and sleeve, respectively, of the trunk plug *P*.

17. Operation.—The method of operating this trunk is as follows: The order having been received over the order wire, the trunk operator tests the line desired, the busy-test circuit running from the tip of the trunk plug *P* through the high-resistance retardation coil *f* to the ground g'. Assuming that the desired line is not busy, the trunk plug is introduced into the jack. Since the operator at the originating end has not yet taken up the trunk, the relay *R* is not energized and the movable springs close the circuit through the outer points *3*, *4*. The current from the battery *B*, after passing

through the coil of the disconnect signal *d*, reaches the points *c*, where it divides equally between the halves of the repeating-coil winding *c* and the two sides of the trunk. Since, under these conditions, there is no return path for it from the outgoing end, the current does not flow and therefore the signal *d* is not displayed. When the operator at the outgoing end takes up the trunk by inserting a plug in one of the multiple jacks, the relay *R* becomes energized, the movable springs are pulled from the points *3*, *4* and closed against *1*, *2*, thereby grounding the center point of the trunk. Current can now flow from the battery *B*, through signal *d* and equally through the two sides of the trunk, which are now in parallel, to ground *g*. As a result, the shutter of the signal *d* is exposed to the operator, thus affording her a signal that the trunk is in use.

On the completion of the conversation and the consequent withdrawal of the plug from the jack at the outgoing end, the relay *R* ceases to be energized and the movable springs fall from the inner points, again closing against the outer ones. The circuit for the battery *B* is again broken, the signal *d* ceases to be energized, and its aluminum shutter falls out of sight of the operator, thus signaling to her the fact that the trunk has been cleared at the outgoing end.

TRUNKS BETWEEN CENTRAL-ENERGY EXCHANGES

18. With the circuit trunks between central-energy offices, an additional advantage is gained in the fact that the operator at the outgoing end receives an automatic signal not only when the calling subscriber hangs up the telephone, but also when the called subscriber does the same. The manner in which this is done will be understood when the nature of the central-energy trunk is studied. Fig. 6 shows the wiring of this trunk. The repeating coil has been removed from the outgoing end and the ring r' of the jack is connected through a 36-ohm resistance coil *a* to ground. But a repeating coil has been retained at the incoming end. The side of the trunk connected to the winding *e* of the repeating coil

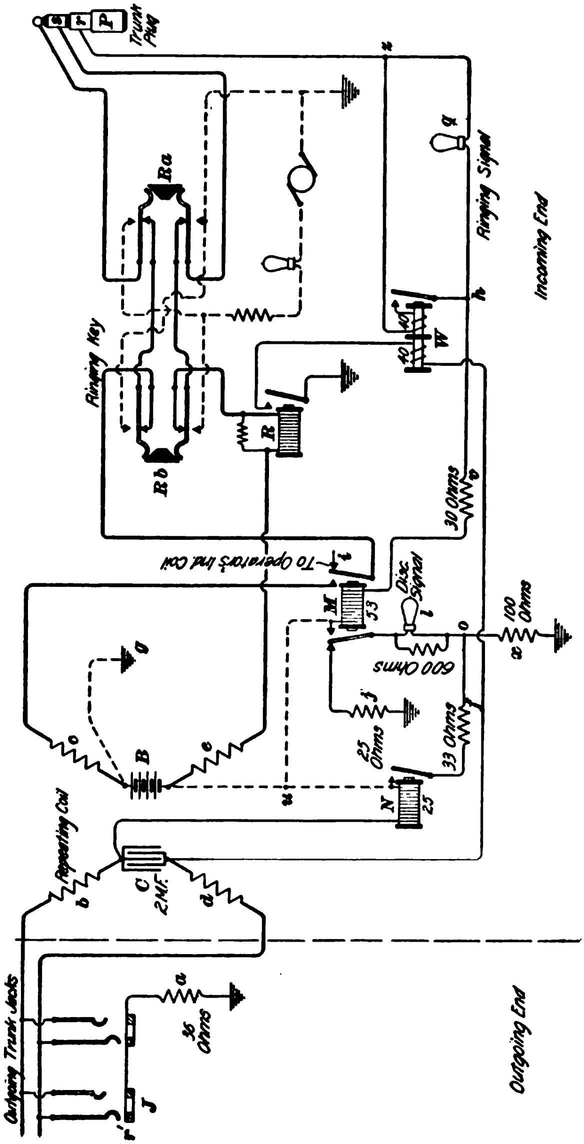

Trunk Plug
Ringing Key
Ringing Signal
Incoming End
To Operator's Ind. Coil
Disc. Signal
30 Ohms
100 Ohms
600 Ohms
25 Ohms
33 Ohms
Repeating Coil
2 M.F.
Outgoing Trunk Jacks
36 Ohms
Outgoing End

FIG. 6

passes through the coil of a relay *R*, and the contacts of the ringing key to the sleeve *s* of the trunk plug *P*. The tip of the plug may be traced through the contacts on the opposite side of the ringing key to one of the movable springs of the relay *M*. The outer point *i* of this relay, against which one movable spring rests when the trunk is idle, is connected to the third winding of the operator's induction coil, and forms the busy-test circuit. The relay *M* is connected in the circuit *g*–*B*–*u*–*M*–30-ohm resistance *v*–lamp *q*–ring *r* of plug *P*. The armature of the relay *N* is connected through a 33-ohm resistance coil *f* to the point *o* where the circuit divides, one branch passing through the 100-ohm resistance coil *x* to ground, while the other branch passes through the lamp *l*, across the terminals of which a 600-ohm resistance is connected, to one spring of the relay *M*. When the relay *M* is not energized, the left spring touches the outer contact and the circuit is continued through a 25-ohm coil *j* to ground. A fourth relay *W* is equipped with two windings connected as shown.

19. Operation.—The trunk operator, having received a call, makes the busy test in the manner explained. Finding the line clear, she introduces the plug into the jack, thereby allowing the current to pass from the 24-volt battery *B* through *u*–*M*–*v*–*q*–ring *r* of the plug–ring of the jack-cut-off relay of the subscriber's line–ground. As a result, the lamp *q* is lighted and the relay *M* energized. When this happens, the right-hand spring breaks contact at *i* with the operator's busy-test circuit and completes the trunk talking circuit. The left-hand spring cuts out the 25-ohm coil *j* and contact is made through the inner point with the battery, thereby causing current to flow through the lamp *l* and the resistance *x* to ground. Thus, when the trunk operator inserts the trunk plug in a subscriber's jack, assuming that the subscriber operator has not yet taken up the trunk, both lamps *q* and *l* are lighted.

When the subscriber operator introduces the calling plug of a standard central-energy cord circuit into one of the

multiple trunk jacks, as *J*, a path is formed from the battery through the sleeve side of the subscriber-operator's cord and plug–sleeve of the trunk jack–winding *d* of the repeating coil–one winding of relay *W*–the contact of the relay *R*, where the circuit remains open until *R* is energized. The tip side of the subscriber-operator's cord circuit being connected to the grounded side of the battery, current can flow through *b–N–B–g*; consequently, the relay *N* is energized, the armature is pulled up against its contact, and the 33-ohm resistance *f* forms a shunt from *u*, around the disconnect-signal lamp *l* and its permanent shunt, to *o*. The resistance of *f* is low enough to prevent sufficient current from passing through the lamp *l* to light it. The called subscriber having been rung up, the relay *R* will be energized when the receiver is removed from its hook, thereby connecting the sleeve side of the subscriber-operator's cord circuit through *d* and one winding of *W* to ground. As a result, the supervisory relay on the calling side of the subscriber-operator's cord circuit is energized and the corresponding supervisory lamp is shunted out, the relay *W* is energized, and a shunt circuit is formed from the point *h* through the armature of the relay *W*, its contact point, and second winding to the point *z* around the lamp *q*, thus putting out this lamp.

20. On completion of the conversation and the consequent hanging up of the called-subscriber's receiver, the relay *R* ceases to be actuated, its armature falls from the contact point, and the circuit from the sleeve side of the subscriber-operator's cord through *d* and one winding of relay *W* is broken. As a consequence, the shunt circuit around the subscriber-operator's calling supervisory lamp is opened and the supervisory lamp lights, the action being exactly the same as if the connection were established between two subscriber lines in the originating exchange. When the circuit is broken, however, the relay *W* is maintained in an energized condition by means of the current from *B* through *u–M–v–h*–armature–contact–one winding of the relay *W–z*–ring *r* of plug–ring of called-subscriber's jack–cut-off relay to ground. The

shunt circuit around the lamp *q* is, therefore, still maintained. The subscriber operator at the originating office, on receiving the disconnect signal in the manner described, withdraws her calling plug from the trunk jack, thus breaking the path for the current from the battery *B* through the relay *N*–coil *b*–tip side of trunk–subscriber-operator's cord circuit to ground. The relay *N* ceases to be energized and its armature falls from the contact, thereby removing the shunt *f* from around the disconnect lamp *l*, which lights and thus gives the trunk operator the signal that the trunk has been disconnected at the other office. On perceiving this, the trunk operator withdraws the plug from the called-subscriber's jack.

21. Guard Lamp.—The lamp *l* also serves as a **guard lamp** to notify the trunk operator of her mistake in case she should disconnect in the midst of a conversation. Assuming the trunk to be connected to a subscriber's line through the trunk plug *P* at the incoming end, if the trunk operator should disconnect, the relay *M* would cease to be energized, and a circuit would be formed from the battery *B* through *u*–contact and armature of the relay *N*– resistance *f*–the point *o*, where it would divide, part going through the 100-ohm resistance *x* to ground and part through the lamp *l*–armature and outer contact of the relay *M*–25-ohm resistance *j*–ground. The 100-ohm resistance *x* would then form a shunt around the lamp *l*; but its resistance is sufficient to prevent the lamp from being shunted out and it would therefore burn with usual brilliancy, giving the trunk operator the signal that the trunk was still held at the originating office.

22. Repeating, briefly, the sequence of events, it should be understood that, when the trunk operator inserts the trunk plug in a subscriber's jack and before the subscriber operator has inserted her calling plug in the trunk jack, both lamps *l*, *q* light. When the subscriber operator inserts her calling plug in the trunk jack, the lamp *l* is shunted out. When the called subscriber removes the receiver from the hook, the lamp *q* and the supervisory lamp in the subscriber-operator's calling cord are shunted out. When the called

subscriber hangs up the receiver on completion of the conversation, the supervisory lamp in the subscriber-operator's calling cord lights up, the subscriber operator clears the trunk and the lamp *l* lights, giving the trunk operator the signal to clear out. Should the trunk operator "cut off" too soon, the lamp *l* lights, thus serving as a guard signal.

In regard to the nature of the apparatus used, the relay *R* is the ordinary supervisory relay used in a subscriber-operator's cord circuit. The relay *N* is of the same type as *R* in regard to mechanical construction, but since it is not placed in the talking circuit, it has only one winding, of about 25 ohms resistance, and no non-inductive shunt. The relay *M* has two springs, controlled by one armature, that break contact with the outer points and make contact with the inner points when energized, and is wound to a resistance of 53 ohms. The relay *W* has two windings of 40 ohms resistance each.

AUTOMATIC RINGING KEYS

23. The latest improvement made on the circuit trunk, in order to reduce the work required of a trunk operator, is the use of what is known as the **machine, or automatic, ringing key.** This is a key provided with a mechanical catch and a magnetic release. When the key is depressed by the trunk operator, the catch holds it in such a position that the current from the ringing machine is sent out on the line, either continuously or at predetermined intervals, until the subscriber removes the receiver from the hook, then the magnetic release trips the key and automatically cuts off the ringing current. With this circuit, the trunk operator cannot ring into the ear of a subscriber who answers a call before the operator stops ringing, and no ringing signal lamp, as *q* in Fig. 6, is necessary.

24. Two-Party Automatic Ringing Key.—A trunk circuit provided with a two-party automatic ringing key is shown in Fig. 7. The free, or ungrounded, side of the ringing generator *G* is connected through a resistance of

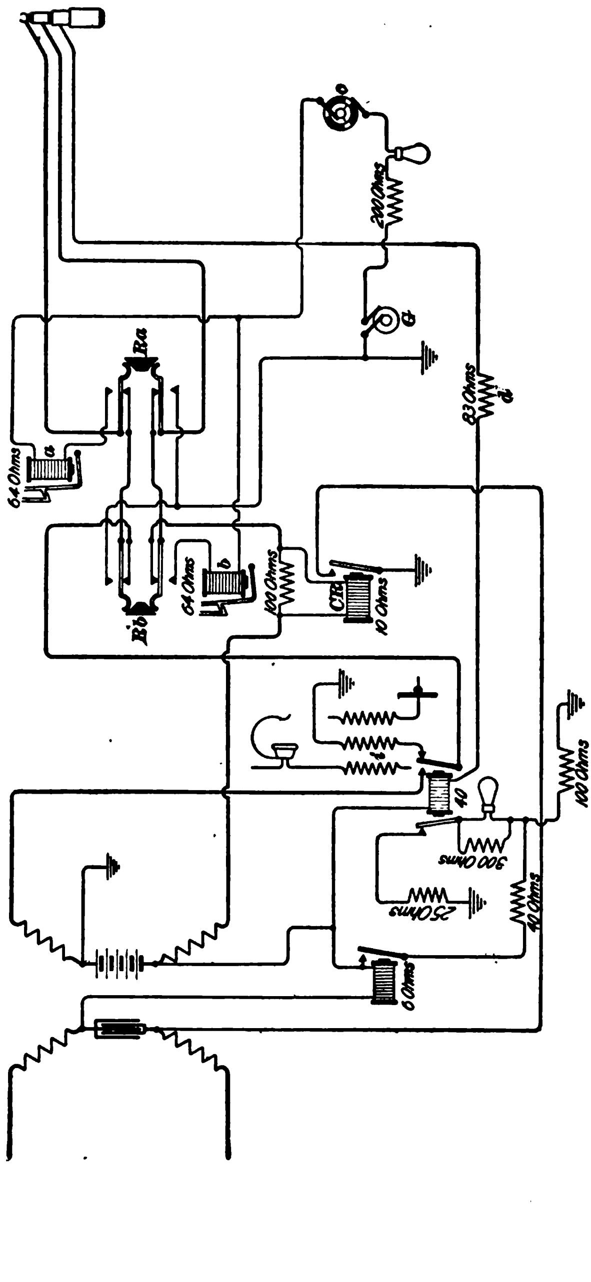

200 Ohms
83 Ohms
64 Ohms
Ra
Rb
64 Ohms
100 Ohms
CR
10 Ohms
40
300 Ohms
25 Ohms
40 Ohms
100 Ohms
6 Ohms

FIG. 7

200 ohms–lamp–interrupting commutator *c*–coil *a* to one side of the ringing key and by a similar coil *b* to the other side. The electromagnets *a*, *b* are used to trip the catch of the ringing key and are so designed that, when energized, the armatures are drawn in and release the mechanical catch, which allows the ringing keys to return to their normal positions. These electromagnets respond to the alternating current, if sufficiently strong, from the ringing machine *G*.

The operation of the ringing key is as follows: Suppose the right-hand side *Ra* of the key to be depressed, current from the ringing machine, after passing through the interrupter *c*, will flow through the coil *a* to the right-hand side of the key and thence out on the line, returning either metallic or through the earth, according as the subscriber station is metallic or two-party. Owing to the fact, however, that the current must pass through the bell and condenser in series at the subscriber station, the current flowing will not be strong enough to cause the tripping coil to operate and the ringing current is, in consequence, allowed to flow out on the line. When the subscriber removes the receiver from the hook, the bell and condenser are shunted by the primary coil and transmitter, which reduces the resistance of the circuit through the telephone sufficiently to actuate the tripping coil *a*, which instantly releases the catch on the key and allows the contact with the ringing-current springs to be broken. Should the left-hand side *Rb* of the key be used, the action would be identical with that described except that the coil *b* would do the work. The interrupter *c* is used merely to produce intervals of silence. It has been found more desirable to have the subscriber's bell ring intermittently than continuously, as it is just as likely to attract attention without causing the subscriber undue annoyance. If it were not for the presence of this interrupter, the bell at the subscriber telephone would, when the key is depressed, ring continuously until the receiver was removed from the hook. The interrupter is usually connected so as to produce intervals of 4 and 8 seconds, respectively; either interval can be used as the silent interval, the

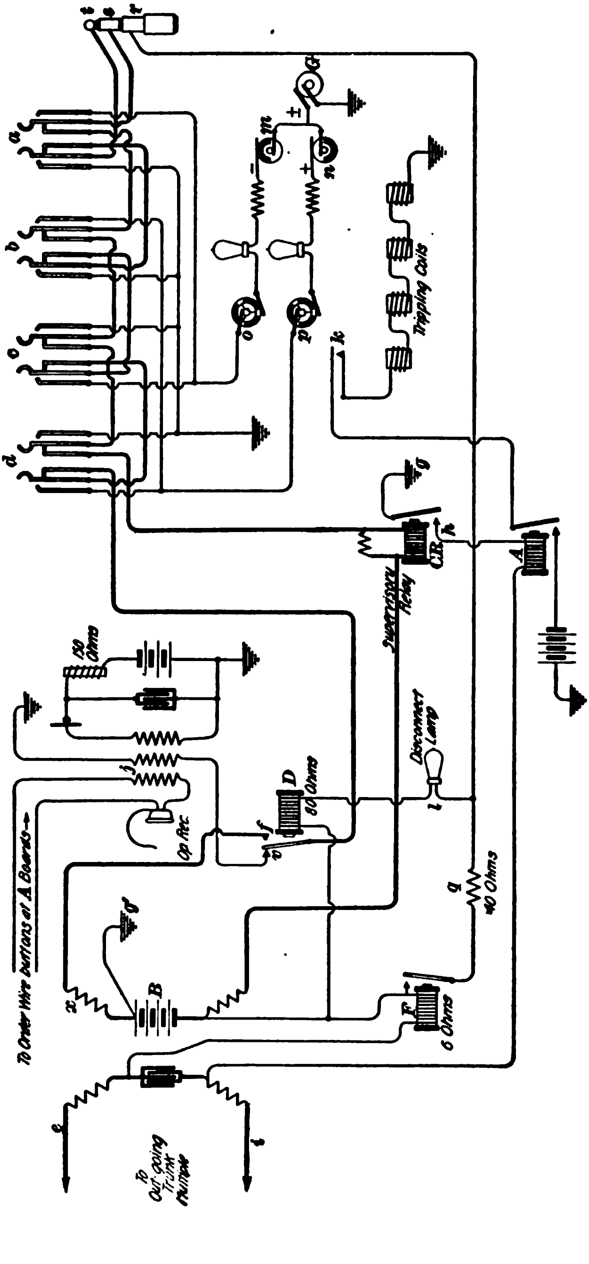

Tripping Coils
Supervisory Relay
C.R.
Disconnect Lamp
80 Ohms
40 Ohms
6 Ohms
150 Ohms
Op. Rec.
To Order Wire buttons at A Boards
To Out-going Trunk Multiple

FIG. 8

other one being used to produce the ringing. The usual practice is, however, to ring on the 8-second interval with 4-second interruptions. The operation of the trunk circuit is, otherwise, the same as explained in connection with Fig. 6.

25. Four-Party Automatic Ringing Key.—A later, but similar, trunk circuit provided with a four-party automatic ringing key and for use between two central-energy exchanges is shown in Fig. 8. The operation of this key is practically the same as the two-party automatic key; the only difference lies in the manner of obtaining four-party selective ringing. By means of the key shown in this figure and a generator properly equipped to supply either positive (+) or negative (−) current impulses, either kind of current impulses may be sent over either line wire returning through the ground, thus enabling any of four properly biased and connected bells to be rung. Two oppositely biased bells are connected between each line wire and the ground. An alternating-current ringing generator *G* has one terminal connected to brushes of two commutating devices, one of which *m* allows the negative impulses and the other *n* allows the positive impulses to pass. The commutators *o*, *p*, which run very much slower than *m*, *n*, allow the impulses to pass to the keys for, say, 8 seconds, while for 4 seconds no current can pass.

When key *a* is depressed, minus (−) impulses flow out through the sleeve *s*; when *b* is closed, plus (+) impulses flow out through the sleeve *s*; when *c* is closed, minus (−) impulses flow out through the tip *t*; and when *d* is closed; plus (+) impulses flow out through the tip *t*. The coils of the tripping magnets are connected through the spring contact *k*, the armature of the relay *A* and battery to ground. When any ringing key is depressed, the spring contact *k* is closed; and when the called subscriber removes the receiver from the hook, the supervisory relay *CR* is energized, thus allowing current to flow through *g*–*h*–*A*–*i*–original calling-subscriber's line circuit–*e*–relay *F*–*B*–*g′*, thus energizing the

relay A that causes current to flow through the tripping coils, thereby tripping the key and opening the spring contact k. The relay A remains energized until the called subscriber hangs up his receiver, or until the trunk is cleared.

26. The operation of this circuit may be briefly traced as follows: On receiving an order and stating the trunk to be used, the trunk operator makes the busy test; if the line is busy, a current flows from t through v and third winding j in her induction coil to ground and produces a click in her receiver. If not busy, no click is received, the trunk plug is inserted in the jack, current flows through B–80-ohm relay D–disconnect lamp l–r–cut-off relay to ground, thus lighting l and energizing D, which connects the tip t to the winding x. When the originating, or A, operator inserts her calling plug in the trunk jack (not shown in this figure), the 6-ohm relay F is energized, thereby shunting lamp l and relay D by the 40-ohm resistance q, which causes l to go out, but still leaves D enough current to hold its armature. When the called subscriber takes down his receiver, the relay CR becomes energized; then relay A becomes energized, which trips the ringing key and opens k. When the receiver is hung up, CR and A are deprived of current, which opens the circuit of the calling supervisory relay at the A operator's position, thereby lighting her calling supervisory lamp, on noticing which she pulls out the calling plug, which deenergizes relay F, thus causing the disconnect lamp l to light, on noticing which the trunk operator pulls out her trunk plug, the light l goes out, and all circuits are restored to normal condition.

27. Construction of Automatic Ringing Keys. The automatic ringing key made by the Western Electric Company and shown in Fig. 9 consists of a framework with a small electromagnet e, the armature i of which is so shaped that it engages with a lug m attached to the key, when the key button c is depressed, and holds it in this position.

The contact springs controlled by v are shown in the lower plan view. At c is shown the key button or plunger, by means of which the ringing key is depressed and closed;

at *d*, the mechanical tripping button or plunger; and at *e*, the coil of the electromagnet. When the armature *i* is in its normal, or unattracted, position and the button *c* is depressed, the lug *m* attached to the lever *x* moves down until it is engaged and held by a projection *w* on the armature *i*; the light spring *o* is also pressed against the framework *n*. When the magnet attracts its armature *i*, which is pressed

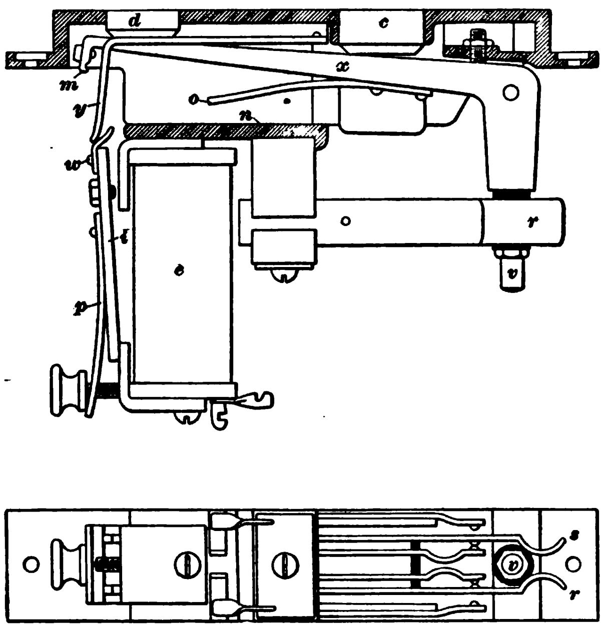


FIG. 9

outwards by the spring *p*, the lug *m* is released, whereupon the spring *o* starts the lever *x* upwards and, together with the tendency of springs *r*, *s* to push the piece *v* to the left, causes the lever *x*, the button *c*, and the contact springs to return to their normal positions. In case the magnet fails to attract its armature or to release the lever *x*, pressing the mechanical tripping button *d* will cause the spring *y* to slide between the armature *i* and the lug *m*, and force them apart, allowing the lever *x* to move upwards.

These keys are made for direct metallic ringing and for two-party and four-party ringing; the principle of construction is the same for all. For two-party ringing, two such keys are used. A four-party ringing key is shown in Fig. 10, in which *w* is a shaft carrying the catch, or trip, for

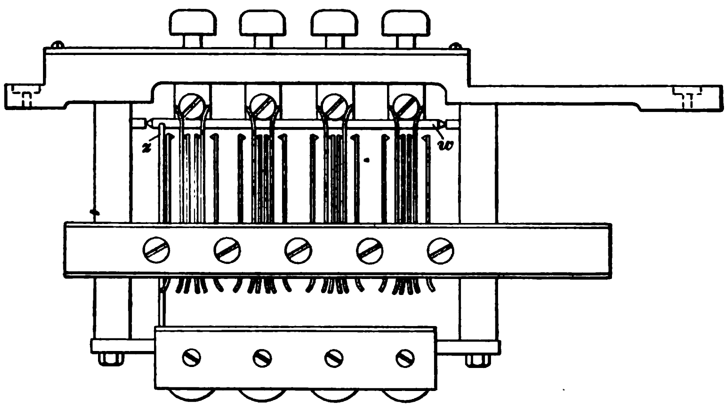
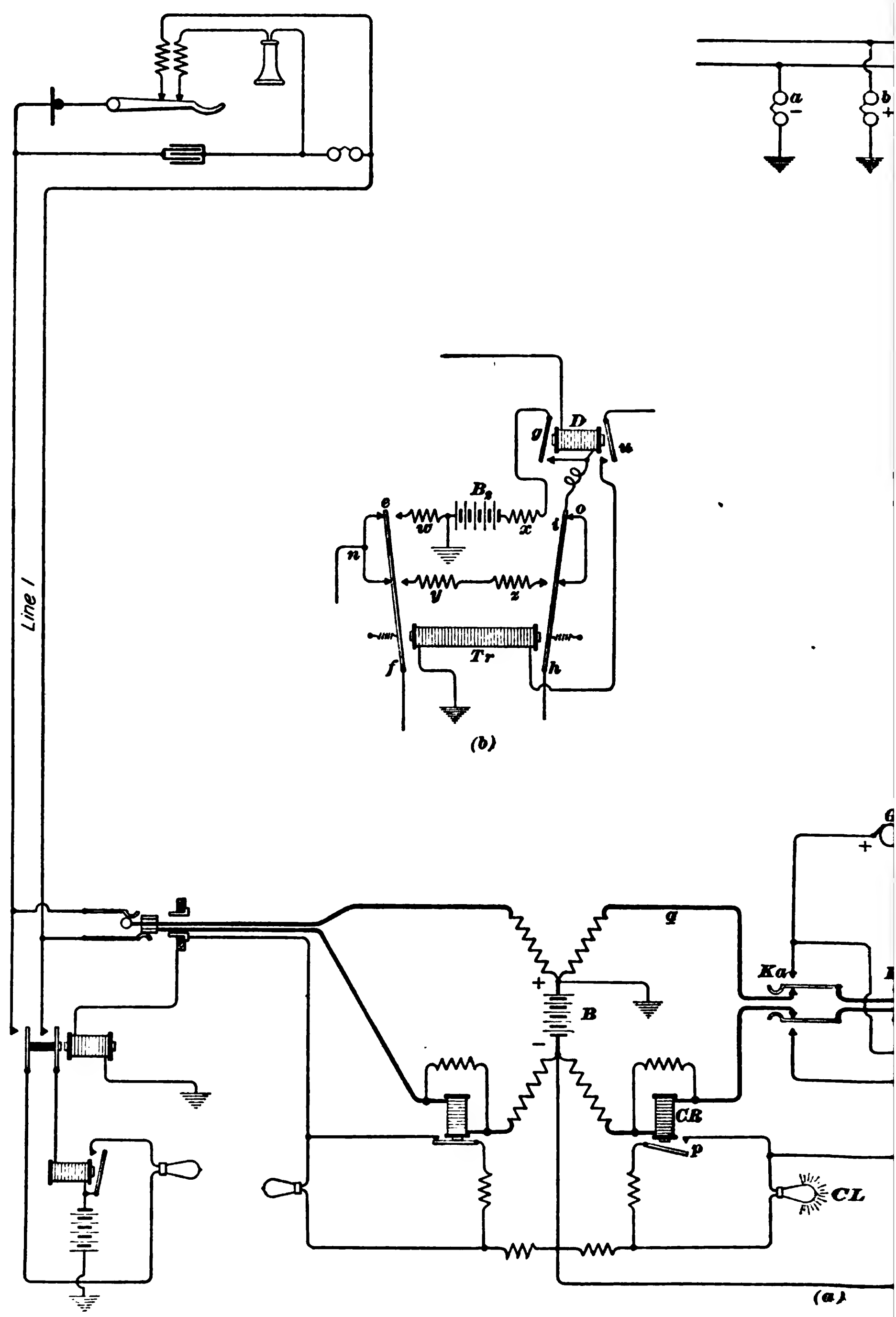


FIG. 10

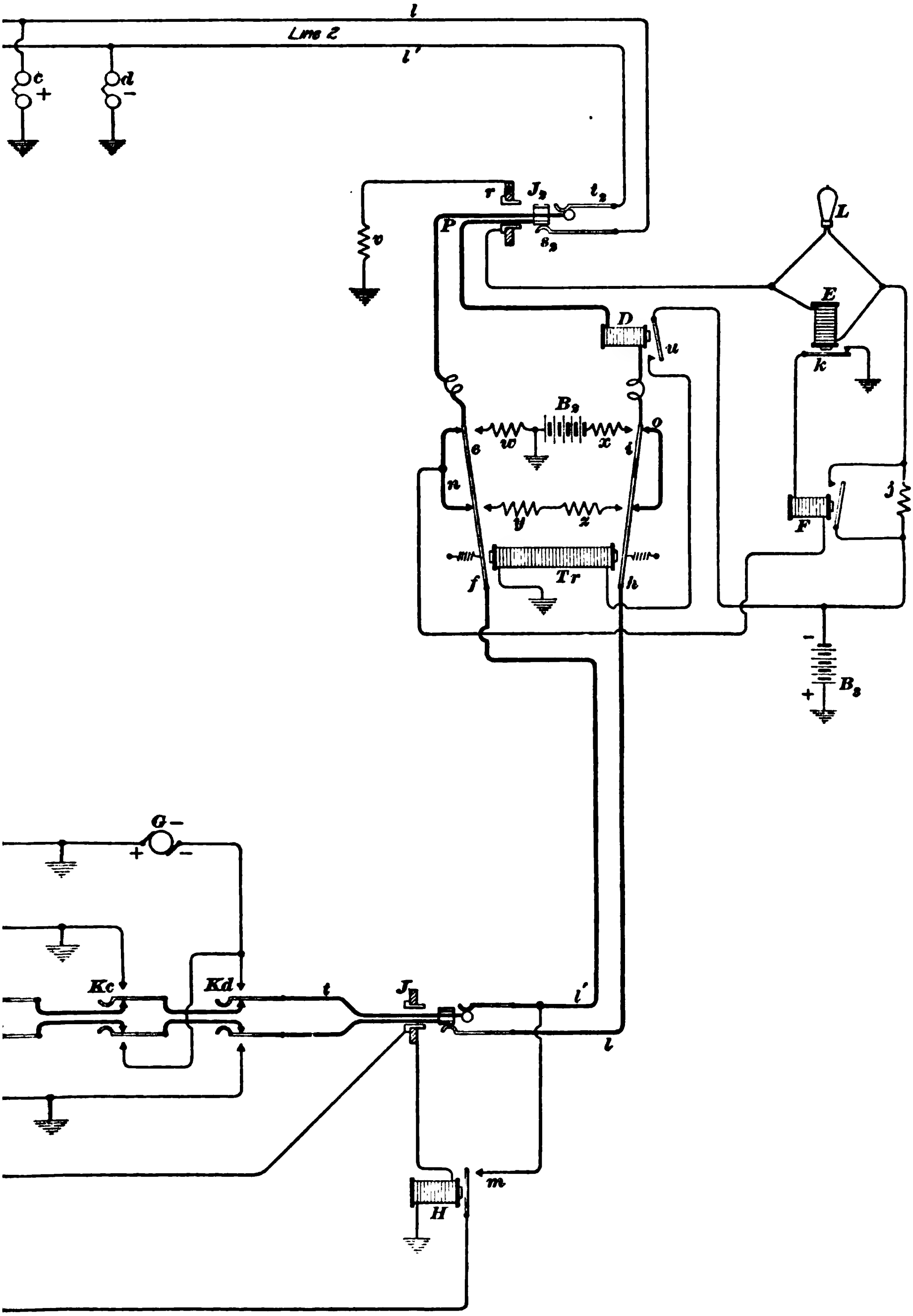
all four keys and *z* is a lever actuated by each armature for releasing, or tripping, the keys.

THROUGH RINGING ON CENTRAL-ENERGY TRUNKS

28. With most central-energy trunk circuits, the operator originally answering the calling subscriber and requesting the extension of the circuit in another central office or even at another board (trunk or toll board) in the same building cannot directly signal the distant called-for subscriber, but must depend on the trunk operator to do the ringing. Through ringing, therefore, is very desirable, especially for long-distance calls, but it is difficult to attain on central-energy trunk circuits on account of the repeating coils, which are efficient for talking currents, but not for the low-frequency ringing currents, and, moreover, they will not transmit unaltered the pulsating selective-ringing currents. The difficulty may be overcome by cutting out the repeating



DEAN THROUGH-RINGING
F



ENTRAL-ENERGY TRUNK

11

coil while the original operator is ringing the called-for subscriber, the ringing current being relayed around the repeating coil; this method has been tried with some success. Mr. W. W. Dean devised for the Western Electric Company circuits and apparatus for accomplishing the desired results.

29. Dean Selective Through-Ringing Trunk Circuit.—Fig. 11 (*a*) shows the connections passing through two central offices, including the troublesome repeating coil *w x y z*, which is here cut out while ringing. By the arrangement shown, the *A* operator supervises, rings, and controls the connection by means of signals. At the left of the figure is shown one subscriber's station, line circuit, and a cord circuit of the Bell central-energy system. The trunk circuit extends from jack *J* to plug *P*. The repeating coil *w x y z* is normally cut out of the circuit.

30. The operation is as follows: The *A* operator, finding that the number requested by the subscriber on line *1* requires trunking and having informed the *B* operator what number is desired and having learned from that operator what trunk to use, inserts the calling plug in the proper trunk jack *J*. The *B* operator inserts the trunk plug *P* in the jack J_1 of the desired line. Sufficient current flows from B_1, through the ground-resistance *v*–*r*–relay *E* and lamp *L* in parallel-resistance *j*–to B_1, to operate the relay *E*, but not enough current flows through *L* to light it because relay *F* is not energized, its circuit being held open at *m* by relay *H*. The *A* operator may ring any one station on a four-party line by means of the four-party ringing keys *K a*, *K b*, *K c*, *K d*, which are arranged so as to send plus or minus pulsating currents through either side of any trunk or subscriber's line. The ringing current returns through the ground.

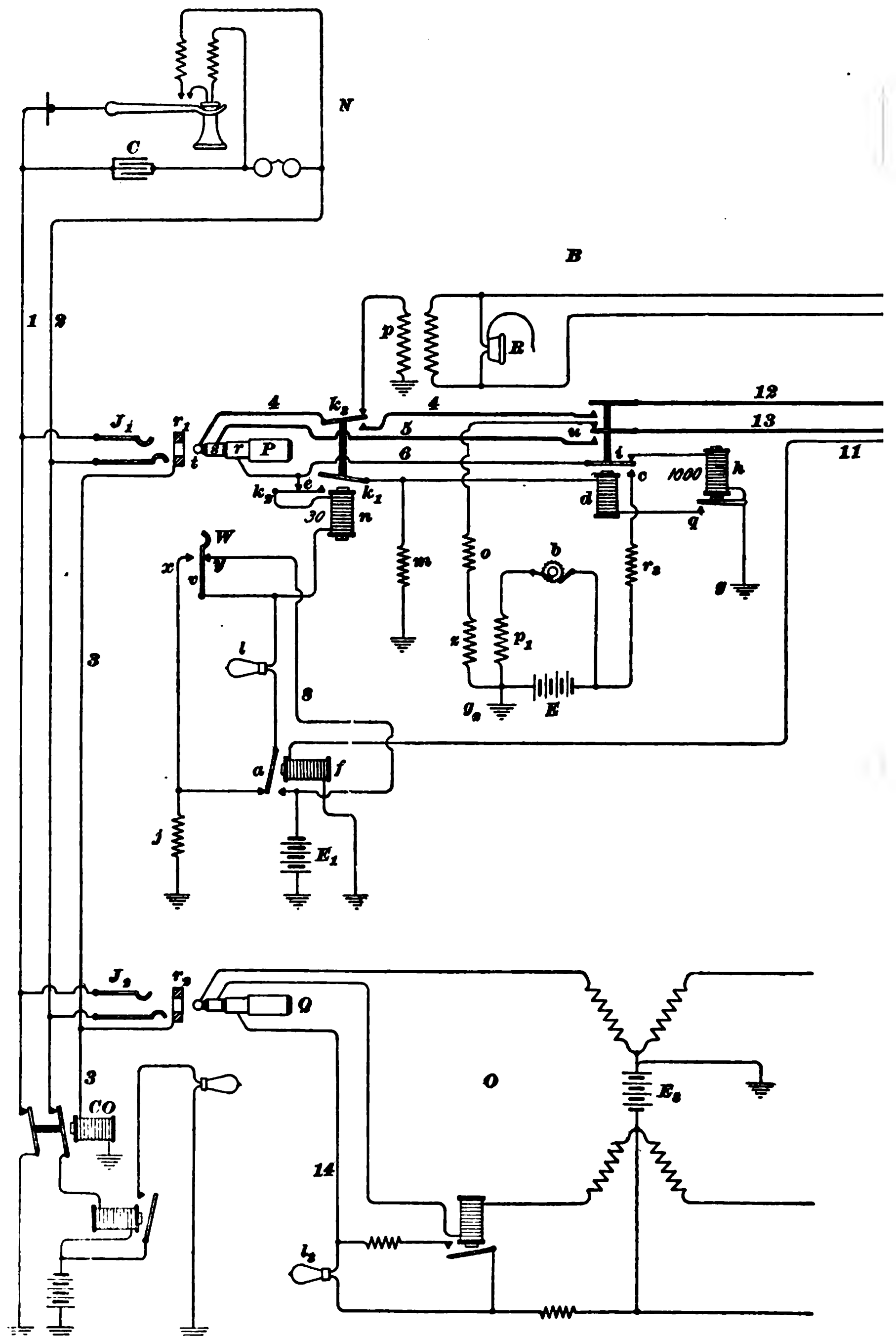
All connections are now exactly as shown in the figure. The ringing current is not now strong enough to close the relay *D*, even if it passes through the sleeve side *l* of the line, because of the high impedance of the subscriber's bell circuit. The relay *D* is so constructed as to be very slow in acting

and also to be operated by the ringing current when strong enough, which would be the case if the subscriber should take down the receiver before the *A* operator released her ringing key. This prevents the flow of the ringing current through the subscriber's receiver with the resulting disagreeable sound and probably a demagnetizing action on the receiver.

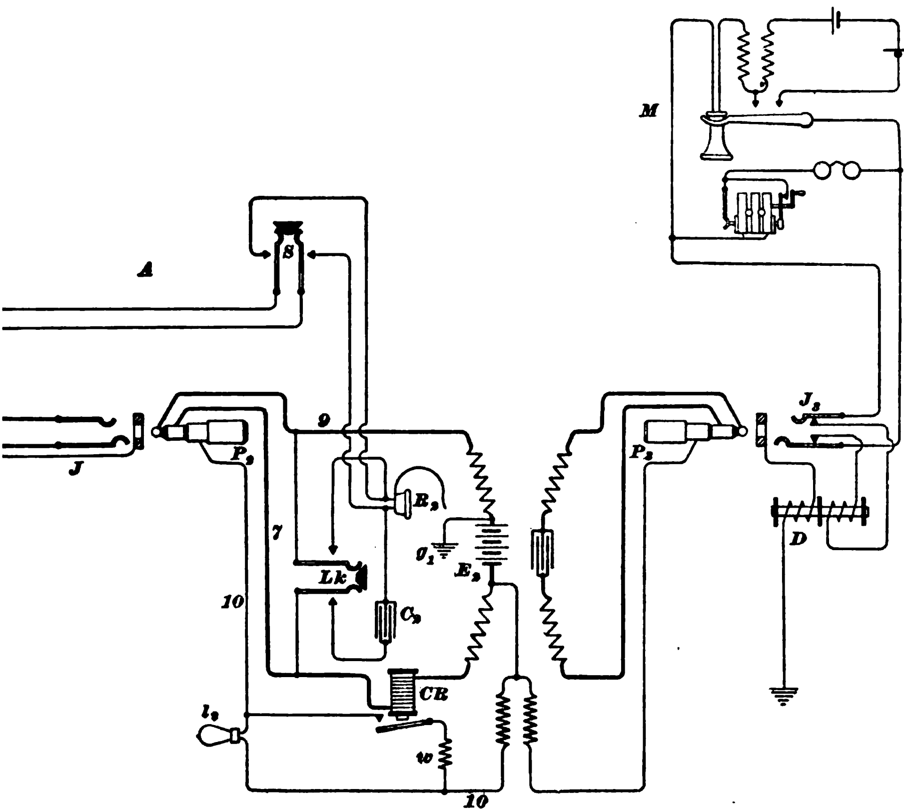
When the desired subscriber on line *2* takes down the receiver and the *A* operator has released the ringing key, current flows from $+B$ through q–t–l'–f–n–e–t_2–subscriber's transmitter and one winding of induction coil–s_2–D–o–h–l–CR to $-B$, thereby operating the relay D, which, in turn, closes relay Tr and cuts the repeating coil $w\,x\,y\,z$ into the circuit, bridging w–B_2–x across the line *2* and y–z across the trunk circuit. The relay D must be so slow in acting that i moves from o to x before the circuit can be opened at u. The Dean slow-acting relay was devised for this purpose. Current now flows from B_2 through line *2* and relay D and hence continues to hold the circuit closed at u so that the relay Tr does not release the levers f, h. Current also flows from $+B$ through q–t–l'–f–y–z–h–l–CR to $-B$, thereby energizing CR and putting out the supervisory lamp CL.

When the receiver on line *2* is hung up, current is cut off from D, thus opening at u the circuit through Tr and restoring the levers f, h to their normal positions, which breaks the circuit of B through $y\,z$, and causes the relay CR to release its armature and the lamp CL to light. On receiving the latter signal, the *A* operator withdraws the calling plug from jack J, which causes H to release its armature, allows current to flow through B–ground–k–relay F–n–f–l'–m–B which causes the armature of F to short-circuit the resistance j, and causes the lamp L to light, which is a signal for the B operator to withdraw the trunk plug P from jack J_2. The practical arrangement of the contacts of the relay Tr is not necessarily the same as indicated in this figure.

31. A slightly different arrangement devised by another person for accomplishing the same result has its distinctive features shown in Fig. 11 (*b*); in all other respects, the



SMYTHE CENTRAL



ERGY TRUNK CIRCUIT

12

circuits are the same. When D is energized, the adjustment of the contacts is such that g closes slightly before u and hence D receives current from B_1 before current from B, Fig. 11 (a), is cut off at o. In this arrangement, there is no tendency for either D or Tr to vibrate, as Tr cannot act before the circuit is closed at g and then at u.

SMYTHE TRUNK CIRCUIT

32. Mr. A. E. Smythe has invented, for the Western Electric Company, a trunk circuit by means of which it is proposed to connect a trunk with a desired line on a multiple switchboard, whether the line is busy or not. If the line is busy, the trunk circuit will be opened, so that there is no disturbance of the existing condition of the line and a busy-back, or tone, test will be put on to so indicate to the original calling operator. As soon, however, as the desired line ceases to be busy, the tone test will be removed, the trunk circuit will be connected through, and the original calling operator will be signaled. This circuit enables an incoming-trunk operator, who has a call coming in over one of the trunk lines to give that call precedence over ordinary calls from local lines.

In Fig. 12, which illustrates the circuits, a trunk line is shown extending from an answering switchboard position A to a trunk board B. M represents a local-battery toll station, N a central-energy subscriber's station connected to a central-energy multiple switchboard, and O a portion of an ordinary cord circuit provided for operators at sections of the multiple switchboard except where the incoming trunks terminating in plugs are located. The incoming-trunk plug P forms the terminal of a trunk circuit extending to the jack J at the A board. The plug P normally rests in the socket W on the keyboard and keeps the spring v against x, so that, normally, no current flows through any relays associated with the trunk circuit.

33. The operation of this trunk circuit is as follows: Assuming that the A operator has a call from toll station M for subscriber N, whose line terminates at switchboard B,

the *A* operator inserts her answering plug P_1 in the jack J_1, thereby automatically restoring the electrical self-restoring drop *D* and putting herself in communication with station *M*. After finding that the call will require the use of a trunk line to board *B*, the operator depresses her order-wire key *S*, gives the number of the subscriber wanted, and, in return, is ordered to use a certain trunk, say the one terminating in jack *J*, in which she then inserts her calling plug P_2. Current now flows from battery E_1 through g_1–ground–g_2–winding *z* of a repeating coil–resistance *o*–contact *u*–conductors *13*, *7* –supervisory relay *CR* to E_1, which causes *w* to shunt and prevent the lighting of the supervisory lamp l_1. This also allows sufficient current to flow through *w* and l_1 in parallel–conductors *10* and *11*–supervisory relay *f*, to operate the latter, which causes current to flow from E_1 through *j*–*x*–*v*, where it divides, part flowing through lamp *l*, which lights, and part through relay *n*–k_1–*e* conductor *6*–*i*–magnet *h* to ground. The lighting of lamp *l* notifies the operator at board *B* that plug P_2 has been inserted in the proper jack *J* at board *A*. The magnet *h* has a resistance of 1,000 ohms and *n* only 30 ohms and fewer turns. Consequently, when *n* and *h* are connected in series, only sufficient current flows to operate the magnet *h*, which then attracts its armature and keeps open the circuit between *q* and *g*.

As soon as plug *P*, in response to the lighting of lamp *l*, is lifted from its seat, the lamp *l* is deprived of current because it is short-circuited by spring *v* and conductor *8*, but current can now flow from E_1 through ground–*g*–magnet *h*–*i*–conductor *6*–*e*–k_1–magnet *n*–*v*–*y*–E_1, thereby exciting only the high-resistance magnet *h*, so that the latter continues to hold open the circuit containing the magnet *d*.

34. Means are provided to allow the *B* operator to make the usual busy test, this being desirable because a called party may have several lines running into the switchboard *B*, as is frequently the case where a subscriber has much telephone business. The *B* operator may then test the several lines of the called party until one is found that is not busy;

the plug being inserted into the jack of that line; but if all the lines test busy, she inserts the plug into the spring jack of any one of the lines regardless of its busy condition.

If the line tested is busy, the rings of all jacks connected to it will not have the same potential as the ground; hence, when the tip t is touched to ring r_1, some current will flow through k_3 and winding p of an induction coil, thereby causing the production of an ordinary busy-test click in the receiver R. If, in spite of the line being busy, the plug P is inserted in the jack J_1, current will flow from E_1 through ground-cut-off relay CO–r_1–r–e–k_2–n–v–y, thereby causing the magnet n to attract its armature, which first brings k_1 into contact with k_2 and then breaks the contact between k_2 and e, thus changing the path of the current without causing it to stop flowing through the magnet n, even momentarily. Current now flows from E_1 through ground-resistance m–k_1–k_2–n–v–y. Thus the magnet n continues to hold its armature, thereby keeping k_1 in contact with k_2 and k_3 in contact with conductor *4*. Conductors *4* and *5* are still open at the contact points under the control of magnet d. Moreover, the magnet h is sufficiently high in resistance not to affect appreciably the operation of the cut-off relay, nor the current flowing in conductor *14*, assuming plug Q to be in jack J_2. Since the battery E_1 is now cut-off from conductor *6* between k_2 and e, the only way through which the magnet h can receive current is the ring of a busy jack.

35. Flowing from the battery E through the winding p_1 of a repeating coil is a current that is continually being interrupted by the device b, thus inducing in the winding z an alternating current that flows through o–u–*13*–*7*–C_2–R_2–conductor *9*–ground g_1, when the listening key Lk is closed. This current produces a characteristic hum, or tone, in the operator's receiver R_2 as long as the line in which the trunk plug P is inserted remains busy, and magnet h, as a result, holds the contact between q and g open. This tone informs the A operator that the desired connection has been made, but that the line wanted is busy. A circuit will also be

completed from battery E_2 through CR–conductors *7–13–u–o–z*–ground; hence, as long as the desired line is busy, the supervisory lamp l_2 will be shunted and remain dark. As soon, however, as the busy condition of the line is relieved, say, by the removal of plug Q from jack J_2, the potential of the ring r_1 is reduced to the potential of the ground, and the magnet h, being deprived of current, allows its armature to make contact with q, thus allowing current to flow from E_1 through ground–g–q–d–k_1–k_2–n–v–y–*8*. The resistance m, which now shunts d, is high enough to allow d sufficient current to attract its armature, thereby closing the circuits between conductors *4* and *12*, between *5* and *13* and between i and c, at the same time disconnecting u from *13* and i from h, so that, although Q has been withdrawn from jack J_2, the cut-off relay CO will continue to get current, but from E through the resistance r_2 instead of from E_2 through conductor *14*.

When subscriber N has finished talking with the first party to whom he is connected through the cord circuit O, he will naturally hang up his receiver. As a result, the lamp l_2 will light up, the plug Q will be withdrawn from jack J_2, and conductor *13* will be practically on open circuit at the subscriber's condenser C, so that no current can flow through the supervisory relay CR; hence the lamp l_2 will light, thus notifying the A operator that the line is no longer busy and that the connection between her cord circuit and the line of subscriber N has been completed.

36. The A operator is provided with suitable ringing keys by means of which she may ring the bell at either station M or N and can also supervise the connections in the usual manner. If the line tested was not busy and the B operator inserted the plug P in the jack the connections now supposed to exist would be immediately established. During the conversation between M and N, the supervisory relay CR holds its armature, thus preventing the illumination of the lamp l_2 and also allowing the relay f to receive sufficient current to hold its armature and prevent lamp l from lighting.

When, after the conversation, subscriber N hangs up his receiver, the relay CR will be deprived of current, which causes lamp l_1 to light and the increased resistance of this circuit deprives relay f of sufficient current to hold it closed, therefore current flows from E_1 through j–a–l–v–y–8, thus lighting the lamp l, which notifies the B operator to withdraw the plug P. Returning this to its socket W opens the circuit at y, thus putting out the light l and depriving both n and d of current, thereby restoring the trunk circuit to its normal condition. The light l_1 goes out when the A operator removes plug P_1 from jack J.

The transmitter circuits at the operators' positions are omitted in this figure, but they would, of course, be necessary and would be connected in the manner usually employed in Bell exchanges.

BELL TOLL AND TESTING CIRCUITS

TOLL BOARDS

TOLL LINES AND CIRCUITS

1. Whenever the business over toll lines, or lines over which a toll rate is charged, is large, the connections are handled at a separate switchboard, which is known as the **toll board.** The usual equipment of this board consists of a multiple of all the toll lines, all the outgoing circuit trunks, including trunks to the main board, and all the outgoing ring-down trunks. The toll lines are equipped with answering jacks, of which about five are placed at each operator's position. In exchanges equipped with the magneto-system, the toll-board circuits have no special features; but in exchanges where the main board is of the central-energy type, the circuits required for the toll board are quite complicated.

2. The circuits handled on a toll board are of two types: The toll lines and ring-down trunks to magneto-offices are of the *magneto-type*, while the outgoing trunks to central-energy offices, whether circuit or ring-down, partake of the features of the *central-energy system*. On this account, the operator's cord circuits must be of two kinds—one to connect together a magneto- and a central-energy circuit and the other to connect together two magneto-circuits.

OUTGOING TRUNK

3. In Fig. 1 is shown an **outgoing trunk** to the main board. The tip springs *t* of the jacks on the toll board are connected to the inner contact *a* of the relay *M*, the armature of which is connected through one side of the ringing key *k* placed at an incoming-trunk position of the main board to the tip of the plug *P*. The outer contact *b* is connected through a third winding of the operator's induction coil to ground. This forms the busy test described in *Bell Trunk Circuits*. The method of using this trunk is the same as that employed with the other circuit trunks. The toll operator transmits the call over an order wire to the incoming-trunk operator

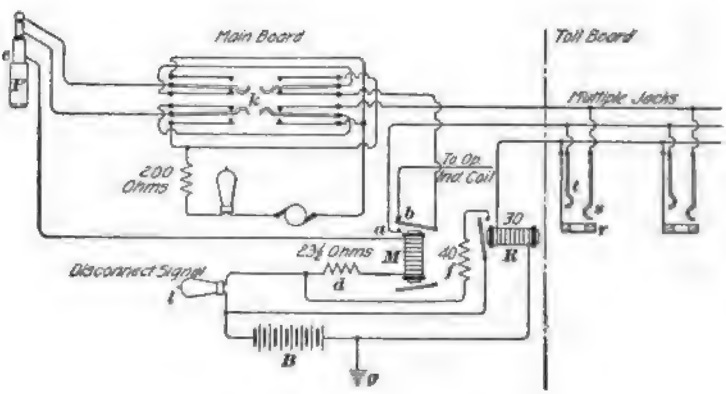


FIG. 1

at the main board. The trunk being assigned and the line called for being tested in the usual manner, the trunk plug *P* is introduced into the jack; current then flows through *g*–*B*–*l*–23.5-ohm resistance *d*–*M*–*e*–cut-off relay–ground, which lights the lamp *l*, energizes the relay *M*, and cuts in the talking circuit to the toll board. The toll operator, on taking up the trunk, that is, inserting a plug in one of the multiple trunk jacks, energizes the 30-ohm relay *R*, which closes the shunt circuit through the 40-ohm resistance *f*, thus putting out the lamp *l*. When the conversation is completed, the toll operator releases the trunk, thereby opening

the relay R and the shunt circuit around the lamp l, which allows it to again be lighted, thus signaling the trunk operator to clear the trunk. The outgoing-circuit and ring-down trunks to other exchanges, being merely an extension of the multiple of these circuits through the main board, are identical with them and need no further description.

SUBURBAN TOLL TRUNK

4. The wiring of a **suburban toll trunk** is shown in Fig. 2. The multiple jacks are shown at J_1, J_2, J_3 and the answering jack at J. The drop D, which is bridged across the line permanently, is provided with a second winding, called the **restoring coil**, one terminal of which is con-

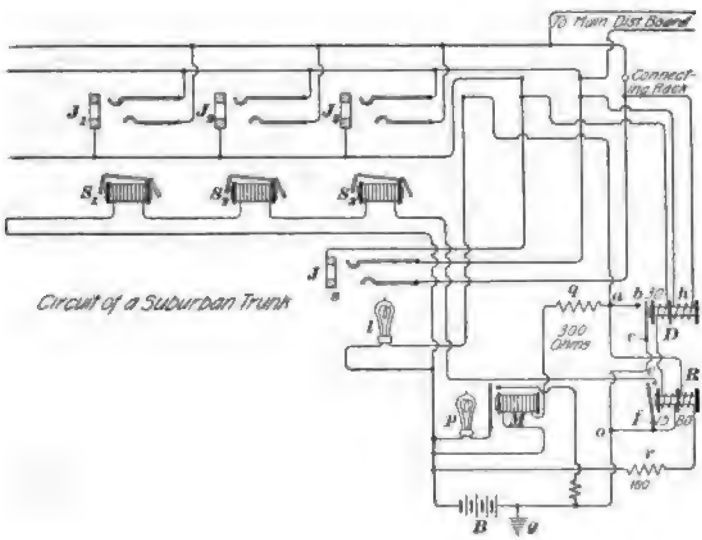


FIG. 2

nected to the collar of the jacks and the other terminal to one winding of the double-wound relay R; the other end of this winding is connected to ground. S_1, S_2, S_3 are **busy signals**, one of which is placed below each multiple jack. These signals are connected in series and consist of an electromagnet, the armature of which, when attracted, holds an

aluminum shutter in plain view of the operator, but which falls out of sight when the coil is not energized.

The method of operating this circuit is as follows: The operator at the distant point, wishing to call up, or **raise**, the toll operator, rings on the trunk in the usual manner and throws the drop *D*. The shutter of the drop, falling against the contact point *b*, allows current from the battery *B* to flow through *l–a–b–c–B*, thus lighting the lamp *l*, and through *M*–300-ohm resistance *q–a–b–c–B*, thus energizing the relay *M* and lighting the pilot lamp *p*; also, through the 160-ohm resistance *r*–80-ohm winding of relay *R–a–b–c–B*, thus energizing the relay *R* and closing the circuit from the battery *B* through the busy signals S_1, S_2, S_3–*e–f–B*. These signals display their shutters, thus notifying the various operators that this trunk is in use.

The toll operator, when she sees the lamp *l* illuminated, inserts a plug in the answering jack *J*, which action allows current to flow from a battery through the shank *s* of the plug and jack–30-ohm restoring coil of the drop *D*–15-ohm winding of the relay *R* back to the battery, thus restoring the shutter of the drop *D* to its original position and breaking the circuits previously traced through its contact *b*. The relay *R* is now energized by the 15-ohm winding and its armature is still held against the contact *e*, thus maintaining the circuit through the busy signals. When the conversation is finished, the toll operator withdraws the plug from the jack, thus restoring the normal condition. The same sequence of events will obtain when the trunk is taken up at any one of the multiple jacks.

TOLL OPERATOR'S CORD CIRCUIT

5. In Fig. 3 is shown one type of toll operator's cord circuit for connecting a magneto-trunk with a central-energy subscriber's line. One half is identical with the ordinary subscriber operator's cord circuit for central-energy switchboards, while the other half consists of the regular magneto-cord-circuit equipment, with special features. One side of the repeating coil is bridged across the cord, while a clearing-out

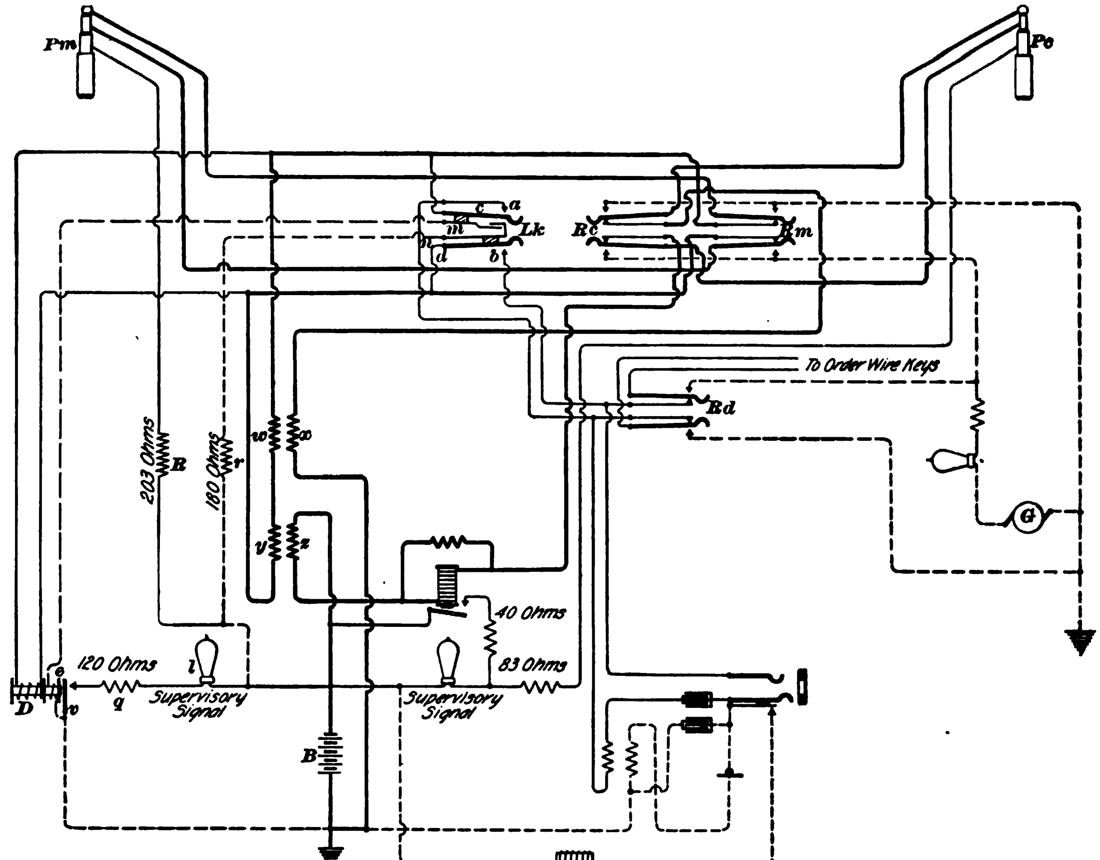

Pm
Pe
a
c
m
Lk
n
d
b
Rc
Rm
To Order Wire Keys
Rd
203 Ohms
R
180 Ohms
r
w
x
y
z
G
40 Ohms
83 Ohms
120 Ohms
l
D
e
v
q
Supervisory Signal
Supervisory Signal
B

FIG. 3

relay *D* of the self-restoring type and a listening key *L k* of special design are provided. The operator's circuit is wired, as usual, to the outer contacts *a*, *b*, the main springs *c*, *d* being bridged across the cord. Two peculiarly shaped springs *m*, *n* rigidly attached to the main springs, but insulated therefrom, are so designed that when the operator listens in they close a circuit including the battery *B*, a resistance *r* of 180 ohms, and the restoring coil *e* on the clearing-out relay *D*. The 180-ohm resistance is used to reduce the current flowing through the restoring coil to its proper amount. When the shutter of the relay *D* is thrown, the circuit through *B*–supervisory lamp *l*–120-ohm resistance *q*–*e*–*v*–*B* is closed and the lamp *l* is illuminated. When the operator listens in the circuit, the restoring coil is closed through the special contacts *m*, *n* on the listening key, the armature of the relay *D* is pulled away from the contact point, and the lamp *l* put out. The ringing generator *G* is connected across the tip and sleeve of the plug *Pc* when the ringing key *Rc* is closed, and across the tip and sleeve of the plug *Pm* when the ringing key *R m* is closed; the ringing current does not pass through the repeating coil in either case. The operation of this circuit should be readily understood, as it resembles so closely those described in preceding Sections. *R d* is a ring-down key used at night, or at other times when an operator may not be constantly listening on the order wires, to ring a bell connected across the order wires in place of the operator's receiver. The cord circuit, used to connect two magneto-trunks, is of the same type as the ordinary magneto-cord circuit, with the addition of the supervisory lamp *l*.

6. Through-Ringing Toll Circuit.—An arrangement devised for use between Bell central-energy and toll-line exchanges is shown in Fig. 4. It gives through, but not selective party-line, ringing. Many times when a subscriber connected to a large exchange is expecting a call from a toll line, some local subscriber calls him and keeps the toll line out of use for a time. This arrangement enables the toll-line

operator to hold the line until she can use it, which should not exceed 10 minutes, however. Suppose that subscriber *A* calls for a party on a toll line. The operator will tell the subscriber that he will be called as soon as the party desired is obtained and to hang up his receiver. The proper trunk plug is allowed to remain in the subscriber's jack, thereby rendering that line busy if tested at any section. A tone test arranged especially for this purpose will be explained presently.

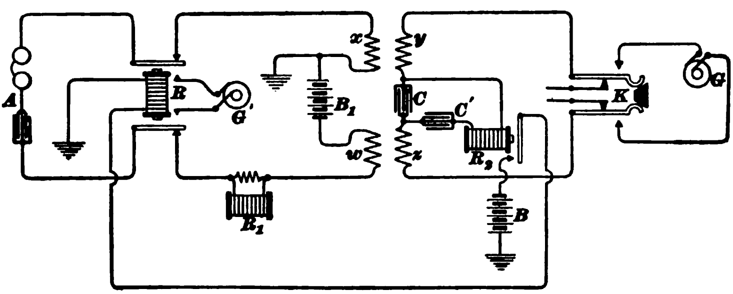


FIG. 4

When the toll operator obtains the party desired, she rings up subscriber *A* by closing the ringing key *K*. Some of this ringing current will flow through the condenser *C*, but enough will flow through the condenser *C'* and relay R_2 to close the latter, which is designed to be operated by an alternating ringing current. The closing of R_2 allows current to flow from *B* through relay *R*, closing the latter and thereby connecting the ringing generator *G'* across the subscriber's line and also disconnecting that line from the circuit containing the battery B_1.

METHOD OF HANDLING CALLS FOR TOLL POINTS

7. The method of handling calls for toll points is as follows: The subscriber operators, in all exchanges provided with incoming trunks from the toll board, are equipped with a sending order wire to a special operator, called a **recording operator,** who receives calls sent over this recording circuit and writes out tickets with the number and exchange from

which the call originates and the point required. These tickets are transmitted to the proper toll operators, who proceed to get the party required. Each toll operator has her keyboard equipped with sending order wires to an incoming-trunk operator in each exchange reached by circuit trunks. On receiving the ticket from the recording operator, the toll operator, therefore, in addition to getting the toll point required, goes in on the order wire to the exchange in which the call originates and orders up the calling subscriber's number. The incoming-trunk operator assigns the trunk, tests the calling-subscriber line, and takes it up, the line having been previously released by the subscriber operator after she has passed the call over to the recording circuit. The toll operator, therefore, comes into communication with the calling subscriber and, having rung up and obtained the toll point required, completes the connection through her cord circuit. The toll operator times the connection, completes the check, and, on completion of the conversation, clears out in the usual manner.

For example, suppose that subscriber number 700, whose line terminates in the 38th street exchange in New York City, desires to talk with subscriber number 17, whose line terminates in the Mount Vernon exchange, which is just outside of New York City. The method of procedure would be as follows: Subscriber number 700, on removing the receiver from its hook, will be answered by the subscriber operator in the 38th street exchange. Learning that he desires to talk with number 17, Mount Vernon, this operator will go in on the recording circuit to the recording operator at the toll board in the Harlem exchange, which is the exchange in New York City nearest to the Mount Vernon exchange, and say "number 17, Mount Vernon, for number 700, 38th street" and withdraw the plug from the answering jack. The recording operator, on receiving the call, will write out a ticket to that effect and it will be transmitted to the operator who handles the Mount Vernon toll trunks. This toll operator will go in on the order wire to the incoming-trunk operator at 38th street and say "700 for Harlem."

The incoming-trunk operator will answer "on 7," as 7 is the number of the trunk assigned. She will then take up, that is connect, number 700 on the trunk assigned, while the toll operator at Harlem inserts a plug in the same trunk, in the meantime raising the Mount Vernon operator on a trunk to that office. When the Mount Vernon operator answers, the toll operator will ask for number 17, and the Mount Vernon operator will connect number 17 to the toll trunk if the line called for is not in use, or will report busy if it is. When the Mount Vernon operator establishes the connection, the toll operator will be in communication with the called and the calling parties and connect them together. The time of beginning and the time of completing the conversation will be noted by the toll operator, the difference being the time elapsed, in minutes and seconds. When the conversation is completed, the Harlem toll operator will ring Mount Vernon, throwing the clearing-out drop and giving the operator at that exchange the signal to clear out, and will release the Mount Vernon trunk and also the trunk to 38th street, thereby giving the operator in the latter exchange the signal to clear out.

TONE TEST FOR TOLL CONNECTIONS

8. From the time the subscriber operator at the 38th street exchange withdraws the plug from the answering jack, after having given the call to the recording operator, to the time that the incoming-trunk operator at the same exchange picks up the connection, there exists an interval during which the calling subscriber's line is not held and can be picked up by any operator who may happen to require that connection; this interval is called the **unguarded interval.** To prevent a line being picked up during the unguarded interval, each subscriber operator in Bell central-energy exchanges is provided with two special circuits known as **tone-test circuits.** They are used to hold lines during the unguarded intervals. Each circuit terminates in a plug that is so wired as to throw on the collar of the jacks of a line into which it is plugged an interrupted current

causing a singing noise. It is also provided with two supervisory lamps, the one lighting up when the subscriber removes his receiver from the hook and the other lighting up when the trunk operator takes up the connection. The subscriber operator uses this circuit in the following manner: After she has passed the call to the recording operator, she withdraws the answering plug from the answering jack and substitutes the plug of a tone-test cord, thus throwing the singing noise on all the jacks of that subscriber's line. Should any operator, other than the incoming-trunk operator who handles the toll connections, desire to establish a connection with the line in question, she will, on testing the line, hear the singing noise of the tone-test circuit and report the line busy. When the trunk operator receives the order from the toll operator, she disregards the tone test and takes up the line. On her doing so, the second lamp on the tone-test circuit lights, thus notifying the subscriber operator that the line has been taken up at the incoming-trunk section and she thereupon withdraws the tone-test plug. Should the calling subscriber desire, for any reason, to attract the attention of the operator during the time the call is being put through, he can, by moving the hook on his telephone up and down, flash the first lamp on the tone-test circuit, thus signaling the subscriber operator that he desires attention. To sum up, the tone-test circuit acts as a busy test to all operators except the trunk operator handling toll connections.

9. Toll Tone-Test Circuit.—The plan of wiring a tone-test circuit is shown in Fig. 5. The current from the battery B passes through an interrupter I across whose terminals the condenser C is bridged, through the primary coil p of the tone-test transformer to ground at g. The relay M is of special design and is provided with a second winding in opposition to the first; one winding has a resistance of 700 ohms, the other a resistance of 300 ohms. When the tone-test plug P is introduced into a jack, the following events occur: Current is sent from the battery through the winding of the relay R, the winding s' of the repeating coil to the ring of the plug P,

thence through the cut-off relay associated with the line to ground. The relay *R* attracts its armature and closes a circuit containing the secondary coil *s* of a transformer, and the winding *p'* of the repeating coil. In this circuit flows an alternating current induced by the transformer in its secondary winding *s*. This current flowing through the winding *p'* of the repeating coil induces in its secondary winding *s'* an alternating current superposed on the direct current from the battery, with the result that a humming noise, or tone test, may be obtained by testing the collars of any jacks on this line and at the same time the battery current holds up the cut-off relay.

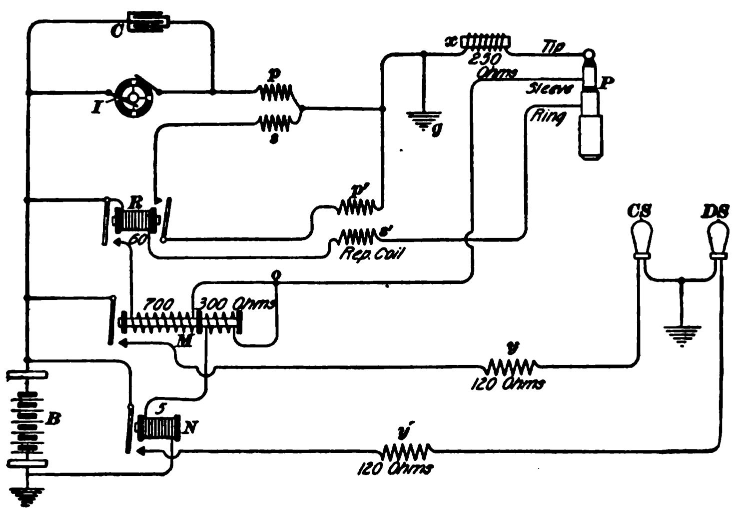


FIG. 5

10. When the left-hand spring of relay *R*, Fig. 5, closes against its contact, it allows the current from the battery to flow through the 700-ohm winding of the relay *M* to the point *o*. The subscriber's receiver being hung up, his line is open; therefore, the only path for the current from the point *o* is through the 300-ohm winding of the relay *M* and the winding of the relay *N* back to the battery. The current flowing through this path does not energize the relay *M*, because it passes through the two windings in opposition, and the

magnetizing effect of the one is sufficiently overcome by that of the other. The relay N is not sufficiently energized to attract its armature, because the two windings of the relay M, being in series with it, introduce a resistance of 1,000 ohms into the circuit, which reduces the current so much that it is insufficient for the purpose. Therefore, the lamps CS and DS remain unilluminated.

When the subscriber removes the receiver from the hook, a path is formed for the current from the point o through the sleeve of the plug–the subscriber's line–tip of the plug–retardation coil x–ground g–battery. This second path forms a shunt to the circuit from the point o through the 300-ohm winding of the relay M and the winding of the relay N. As a result, the total resistance of the branch of the circuit beyond the point o becomes the reciprocal of the sum of the reciprocals of the resistances of the circuits through the subscriber's telephone and the retardation coil x, and that of the circuit through the 300-ohm winding of the relay M and the 5-ohm winding of the relay N. The resistance of a subscriber's line is, at the utmost, 150 ohms, that of the telephone with the receiver off the hook is about 60 ohms, so that, taking in the retardation coil x, the total resistance of this circuit is $150 + 60 + 250 = 460$ ohms. The total resistance of a circuit from the point o through the two relays is 305 ohms, so that the resistance of these two circuits, in shunt, becomes $\frac{1}{\frac{1}{460} + \frac{1}{300}} = 184$ ohms, about. This reduction in the resistance of the circuit beyond the point o is large enough to allow sufficient current to flow through the 700-ohm winding to attract the armature of the relay M, thus closing the circuit through the lamp CS, and causing it to light. It is in this manner that the subscriber attracts the attention of the operator, should he desire to do so while his line is being held on the tone-test circuit. The amount of current passing through the relay N remains about the same as when the subscriber's receiver was hung up, for it still has to pass through the two windings of the relay M. The relay N therefore is not affected by the subscriber.

11. When the trunk operator takes up the call, current is sent from the sleeve of the trunk plug through one side of the line-jack into which tone-test plug *P*, Fig. 5, is inserted -sleeve of plug *P*-point *o*-300-ohm winding of relay *M*-relay *N* to ground. The current flowing along this path encounters the resistance of one side of the trunk repeating coil and the supervisory relay, amounting to about 50 ohms, in addition to the 305 ohms in the two relays. The relay *N* now receives sufficient current through the 300-ohm winding of the relay *M*, mostly from the sleeve of the plug *P* and the 50 ohms in the sleeve side of the trunk plug, to energize it; in fact, the current received is practically independent of the little that may be received through the 700-ohm winding of relay *M*. The relay *N*, therefore, attracts its armature, thus lighting the lamp *DS*. This lamp gives the signal to the subscriber operator that the trunk operator has taken up the connection and the former immediately withdraws the tone-test plug from the jack.

LONG-DISTANCE CONNECTIONS

12. The methods so far considered have been those employed in handling connections between two subscribers' lines terminating in the same exchange, between subscribers' lines terminating in different exchanges lying within the same toll district, and between two subscribers' lines terminating in exchanges lying in different toll districts. The methods employed in handling calls between two points situated at such a distance that the wires of the long-distance company have to be used are an enlargement of those employed in handling toll connections. The calls handled by a long-distance exchange are of a twofold nature: those between two long-distance exchanges in which the connections are completed through the local exchanges, and those between two long-distance exchanges not provided with direct trunks, and therefore requiring the interposition of a third exchange to complete the circuit; in long-distance vernacular, these latter are called *through connections*.

LONG-DISTANCE CIRCUITS

13. The circuits handled in a long-distance exchange are of the following types: *toll trunks*, connecting long-distance offices; *local trunks*, connecting a long-distance exchange with local exchanges; *office trunks*, connecting different sections of the switchboard in the same exchange; *subscriber loops*, connecting long-distance subscribers' telephones with the long-distance exchange, a few of which always exist in large cities; *sending order wires* to all local exchanges equipped with long-distance circuit trunks; *incoming order wires* from all local exchanges similar to a recording circuit, but terminating, in the long-distance exchange, in the telephone circuit of a receiving operator who takes the place of a recording operator at the toll board in a local exchange. The toll trunks terminate in a series of toll-line terminal boards, each containing two operators' positions; five toll trunks are usually assigned to an operator. The outgoing circuit trunks to local exchanges and the sending order wires are multipled before all the toll-line operators. In large long-distance exchanges, there is a special line of boards, called **recording boards,** which are made up of two position sections, the number of these sections being dependent on the amount of business handled. The long-distance subscriber lines are terminated in a third row of boards, called the **subscriber boards;** there is seldom more than one section of two positions required for this purpose. In the large offices, the through connections are handled at a separate set of sections, called the **through boards,** which likewise are made up of two position sections.

14. To illustrate the methods of operating, the first case considered will be a call between a local subscriber and a long-distance point. Let it be supposed that subscriber number 64, whose line terminates in the 18th street exchange in New York City, desires to talk to a party in Philadelphia. Subscriber number 64 will place the receiver

to his ear and raise the subscriber operator at the 18th street exchange in the usual manner. He will then say: Give me Mr. Blank, number 85, Philadelphia. On receiving this information, the subscriber operator will go in on the recording circuit to the long-distance receiving operator and transmit the call. The receiving operator will write out a ticket, which, in form, is identical with that used by the recording operator at a toll board in a local exchange and which she will transmit to one of the unoccupied recording operators, who, on its receipt, will go in on the order wire to the incoming-trunk operator at 18th street and order up the calling subscriber's number. In the meantime, the ticket will be transferred to the toll operator at the toll-line terminal board who handles the Philadelphia toll trunks. She, on its receipt, will proceed to raise the required party in Philadelphia by first calling at the long-distance office in that city an operator who will complete the connection through the proper local exchange. While this is being done, the recording operator will have put herself into communication with the calling subscriber, and will hold the trunk until it is picked up by the toll-line operator when she has secured the desired party in Philadelphia. The connection will be completed through the pair of cords on the toll-line operator's keyboard. If the call came in from another city, as Philadelphia, for a local subscriber, the toll-line operator answering the distant point would raise the called party over a sending trunk to the incoming-trunk operator at the proper local exchange.

Calls from any of the long-distance subscribers having direct lines to the long-distance exchange are handled without the use of the receiving or recording operators. The operator handling these long-distance subscribers' lines, on the receipt of the call, makes out a ticket and transmits it to the proper toll-line operator, who proceeds to get the called party in the manner already described. The connection with the calling party is completed over a trunk between the subscriber board and the toll-line terminal boards.

PNEUMATIC TICKET DISTRIBUTION

15. The system of handling the toll business over a switchboard set apart for this purpose caused the development of the **pneumatic-tube system** for properly distributing the toll checks. When toll boards were introduced, the business handled over them being small, the number of sections required to take care of it was correspondingly small. The toll checks were made out by the recording operator and handed to messengers who carried them to the proper toll operator. With a toll board of not over ten sections, this scheme worked admirably, the messengers being student operators. As the number of sections increased, however, the work of the messengers was increased twofold: first, because of the increase in the number of toll lines; and, second, because of the increased distance over which the messengers had to travel. This latter feature had the additional effect of making the service slower and the two features had the effect of increasing the force of messengers.

To remedy this, there was installed in Chicago a system using belts to which were fastened clips that picked up the tickets from the recording operator's position and distributed them before the proper toll operators. This system was fairly successful, but was defective owing to the fact that it seemed impossible to so design the clips that they would not often either drop the ticket before the proper time, or else would not drop it at all, so that it would be carried around and around with the belt. Again, it was not flexible enough to drop the tickets directly before the toll operator, but would deposit them at intermediate distributing points, from which messengers would carry them to the proper toll positions.

At the Harlem exchange in New York, a toll board was designed in which the recording operator was placed above the toll operators, and a system of chutes led to each toll position. The recording operator, after writing the toll check, merely placed it in the proper chute and it was carried by gravity to the proper toll position. This was the best system devised up to that time and prepared the way for the

pneumatic-tube system; it did away with the use of the messengers, but was limited by the size of the toll board.

One thing that retarded the development of the pneumatic-tube system was the fact that the ticket to be carried through the tube was but a thin piece of paper and presented no surface for the air to catch hold of. This was overcome, after much experimentation, by folding one end of a ticket. Brass tubes with an internal cross-section 2 inches by 1 inch are run from a central distributing table to the toll board; one tube for each two positions. These tubes are closed with valves at both ends when not in use. An exhaust pipe runs from each position to the blowing engine. A common supply pipe runs from the blowing engine to the distributing table, where it branches into feeders, one for each tube to the toll board. From each recording position, tubes run to the distributing table, each being fed by an independent supply pipe at the recording positions, while the other ends are connected to the exhaust pipe. The blowing engine is of special design and is run, usually, by an electric motor.

16. The method of operating this system is as follows: The recording operator writes the check in the usual manner and introduces it into the tube going to the distributing table. Here it is received by a clerk, who having examined it, places it into the tube leading to the proper toll operator, who, on receiving it, proceeds to establish the connection in the usual manner. Placed in front of the tube openings on the distributing table is a row of lamps, similar to those used on the cord circuits for supervisory purposes, one lamp before each tube. When a toll operator is unoccupied, she throws a key placed on the keyboard, which lights her lamp. By this means the clerk at the distributing table knows which toll operators are idle. When more than one operator is handling trunks to the same toll point, this information is useful in enabling the distributing clerk to send whatever tickets come to her for a certain toll position to the operator at that position who is unoccupied. In the case of toll boards that are equipped with the full toll-line multiple, this selection

may be made throughout the whole board. The pneumatic system is still in the experimental stage, but it probably has come to stay. It is the best system that has yet been devised. The time taken by the ticket to travel from the distributing table to the toll board is about 6 seconds.

If the ticket is folded over too much or not enough, it may remain in the tube or at least require a very long time to flutter through to the other end. Besides, on dry days, the handling of the tickets electrifies them so that they are apt to adhere to the sides of the tube. The volume and pressure of air must also be regulated to correspond to the amount of business handled and the tubes require regular and careful cleaning. Another objection to this system is the cost of power, which is said to be $150 a month for a capacity of 40,000 calls a day. Moreover, it is used at its full capacity and greatest efficiency for only a few hours a day.

It has recently been proposed to use telautograph, or writing, machines for this purpose. The recording operator would write the check on one machine and another machine in front of the proper toll operator and electrically connected only to the first machine would automatically rewrite the check. The recording operator could connect her telautograph with that of any toll operator by suitable keys or switches.

OPERATION AND EQUIPMENT OF COMPLETE EXCHANGE

OPERATING FORCE

17. Organization of the Operating Force.—The organization of the operating force in a telephone exchange and the functions performed by each division will be studied first for local exchanges, and then for long-distance exchanges. For, while some difference in detail exists between the two, in general outline the methods of organization and the duties performed are the same for both classes of service. The operating force of a local exchange is in charge of a **manager**, who is in almost every case a man. He has sole and absolute charge of the entire operating force in his exchange, is free to hire and discharge as he sees fit, being subject always to the superintendent of traffic to whom he reports. The manager divides his force into two parts, one being on duty in the daytime and the other at night. The day force is actively supervised and handled by the chief operator, who is the lieutenant of the manager; this official is almost always a woman.

18. The duties of the **chief operator** are to see that the operators report for duty promptly at the required time and that they properly attend to their duties when in the exchange. She assigns the operators to their proper positions at the switchboard, sees that they are properly relieved, arranges the lunch hour, and attends to the general business of the exchange. She makes all the recommendations to the manager for dismissal, increase in salary, and the like.

19. Directly under the chief operator are the **supervisors**, whose duty it is to patrol certain assigned portions of the switchboard to see that the calls are being promptly attended to and to help the operators out of any difficulty

that may arise, or to furnish them with necessary information from time to time. The number of supervisors required depends altogether on the size of the office and the amount of business handled; in one exchange in New York City, there was, in 1905, one supervisor for each eight or nine operators. The supervisor walks up and down behind her operators to watch, assist, and supervise their work. There being duplicate receiver jacks at each operator's position, she may insert her own receiver plug in the idle jack and assist an operator whenever necessary.

20. The next official is the **monitor,** who acts as a special operator, helping the operator out by taking up all connections that she is unable to complete in the usual manner. She also supervises the work of the operators in handling the business. To her are referred, by the operators, all causes of trouble, all "don't answers," and all cases where the subscriber requires information. All the troubles referred to her are entered in a record, which is sent to the wire chief for action. The "don't answers" in which the non-answering party's line lies in her own exchange are tested out by her trying to get a response. Those in which the non-answering party's line lies in some other exchange are referred by her to the monitor of that exchange. All "don't answers" in which she fails to get a response are referred to the wire chief for action.

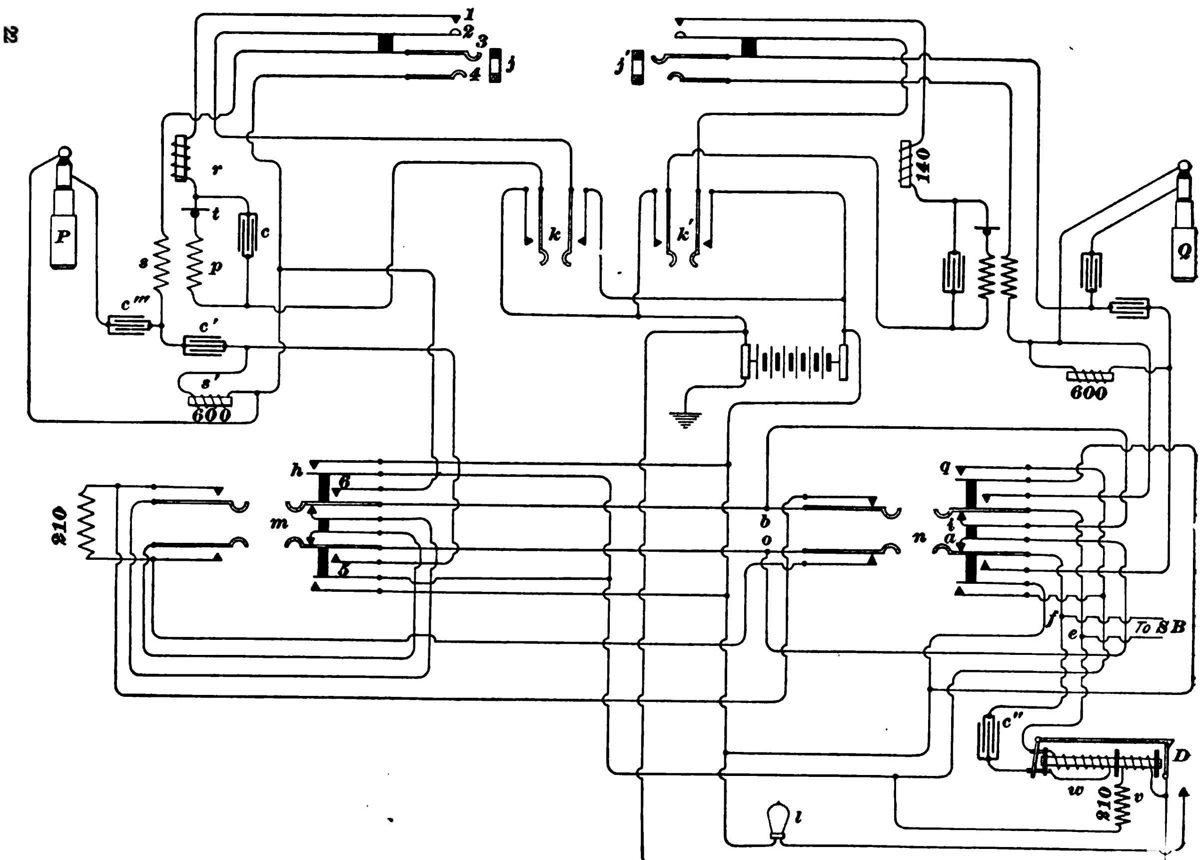
Next to the monitor come the **operators,** who should attend to all calls received as quickly and politely as possible. Each operator has her own head-set, which may be merely a head-band receiver or a head-band receiver and breast-plate transmitter, the latter equipment now being considered the more advisable. When an operator is about to be relieved, the one taking her place inserts her plug in the idle jack and gets the general run of business before the retiring operator leaves.

The night force is presided over by the **night manager,** who reports to the manager. He has under him a night chief operator and a night monitor, in addition to the night operating force. The duties of the night officials are identical with those of the day officials.

COMPLETE EXCHANGE EQUIPMENT

21. Manager's Desk.—The manager, chief operator, and monitor must use certain apparatus and special circuits in order to properly attend to the business. The manager sits at a specially designed desk, which has a flat top with a box-shaped cabinet placed on it. This cabinet is equipped with jacks connected across the listening circuit of each operator's set, jacks across the listening circuit of each outgoing order wire, jacks across the lines from the switchboard to the manager, jacks across the lines from the monitor's and chief operator's desks, together with the lamp signals. These circuits, which are quite simple, need no further description, except to say that they are duplicated on the other side of the cabinet, in order that the assistant manager, sitting on the opposite side of the desk, may also have access to them.

22. The **manager's talking circuit**, which is of special design, is shown in Fig. 6. The primary circuit runs from the battery through the key *k*–contacts *1* and *2* of jack *j*, which are closed when the receiver plug is introduced–retardation coil *r*–transmitter *t*–primary winding *p* of induction coil–battery. The condenser *c* is bridged across the circuit so as to include *t* and *p*. The secondary circuit includes a secondary coil *s* and the condenser c', from which it goes through contact *5* on key *m*, which is now supposed to be closed–point *o*–contact *a* of key *n*–condenser c''–winding *w* of drop *D*–contact *i*–point *e*–contact *i*–point *b*–contact *6* of key *m*–spring *4* of jack *j*–manager's receiver–contact spring *3* to coil *s*. The line from the switchboard is bridged on the points *e* and *f*. The coil s', which is bridged across the receiver circuit, has a resistance of 600 ohms, is of high impedance, and is used to keep the line normally closed, in order that the manager, by throwing the key *m*, can light the line lamp at the switchboard. The keys *m*, *n* have two sides; when either key is closed on the left side, a 210-ohm resistance is bridged across the line to the switchboard. This coil, which is sometimes termed a *holding coil*, is used by the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l

Fig. 6

manager when he desires to temporarily hold a line while he is talking on another. By keeping the line closed, it prevents the supervisory signal from being lit, and the operator, therefore, from taking down the connection. The plugs *P*, *Q* are also bridged across the receiver circuits. Either may be used to plug into the jacks on the listening circuits in order to inspect or supervise the operator's work. The keys *m*, *n* serve also, when thrown to the right, to close, at *h* or *q*, the circuit through the restoring coil *v* of the drop *D*. The signal lamp *l* is connected as usual, so that, when the drop is thrown, the circuit is closed and the lamp is lit; and when the drop is restored, the circuit is broken and the light is put out. There are two circuits, one nearly a duplicate of the other, each being provided with about the same equipment. One of these circuits is for use by the manager, and the other for the use of his assistant.

23. Chief Operator's Desk.—The desk and circuits for the chief operator are the same as those used by the manager; the equipment is duplicated for the chief operator's assistant. The desk used by the monitor has the form of a switchboard, but with a very low top. The keyboard is equipped with eight pairs of cord circuits, which are the same as those used by the subscriber operator. The face of the desk is equipped with jacks on the listening circuits to each operator's receiver, jacks on the listening circuits to each sending order wire, jacks on the line from the switchboard, and jacks on the lines from the manager's and chief operator's desks.

ARRANGEMENT OF EXCHANGE APPARATUS

24. Front of Switchboard.—In Fig. 7 is shown one subscriber operator's position on a central-energy switchboard built by the Western Electric Company. There are three panels to each operator's position and each operator attends to 180 subscribers having measured-service rates. Each panel has, as shown at *A*, six rows of line lamps, each lamp having its corresponding answering jack immediately above it. At *B* are shown the line-pilot, supervisory-pilot

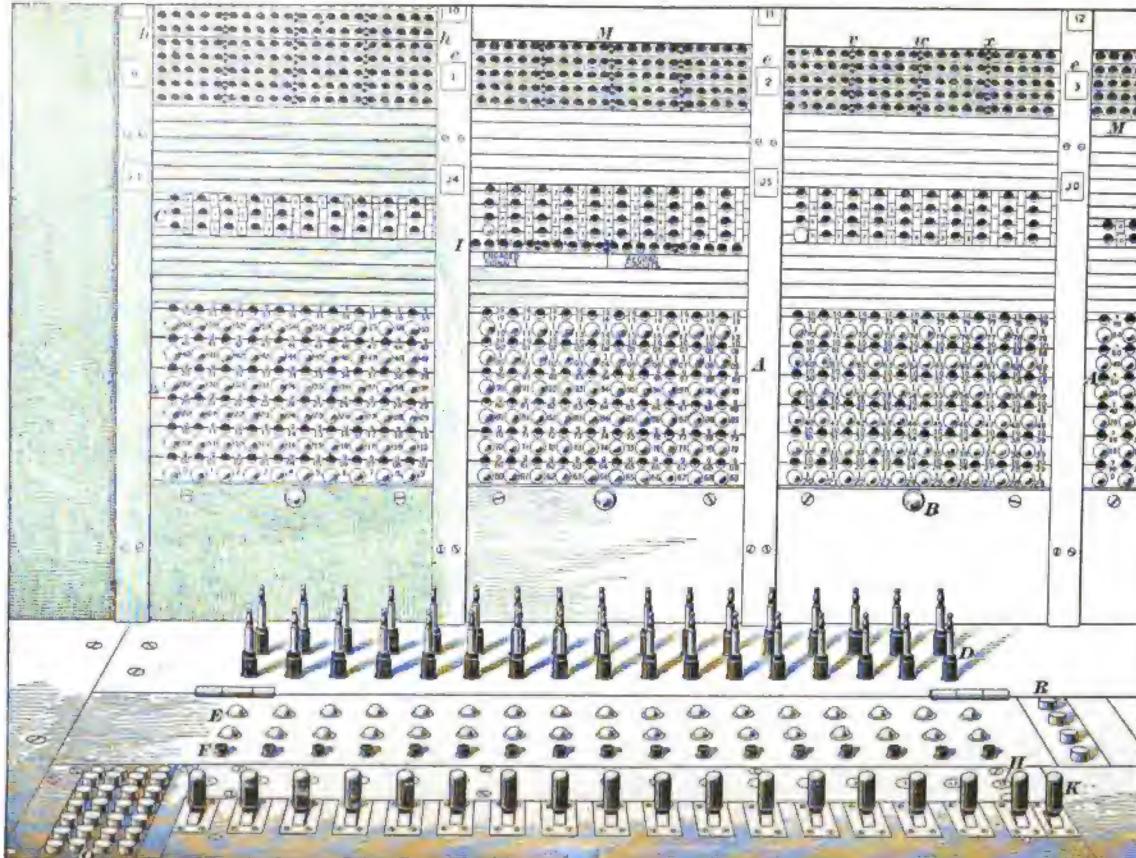


Fig. 7

and meter lamps. A complete section of the multiple includes three operators' positions, so that one multiple section suffices for each 540 subscribers. At *J3*, *J4*, *J5* are shown the outgoing trunk jacks, and at *I*, a row of don't-answer, busy-back, and other jacks used for miscellaneous purposes. In the United States, the busy-back and don't-answer jacks for the incoming-trunk positions are usually located just below the answering-jack space, instead of in the row *I*, as shown in Fig. 7, where they are designated as engaged and record signals.

25. Arrangement of Multiple Jacks.—Above the trunk jacks, designated by the letters *J3*, *J4*, etc., are grouped the multiple jacks *M*. These are grouped in banks containing five strips of twenty jacks each, each group being separated from the one above by thin white holly strips, as shown at *a b*, *c d*, Fig. 8, and at *h h*, Fig. 7. Each bank of jacks is numbered from *0* to *99*, Fig. 8, and each jack in each bank has a permanent number stamped on the rubber mounting, with the exception of the fifth, tenth, and fifteenth

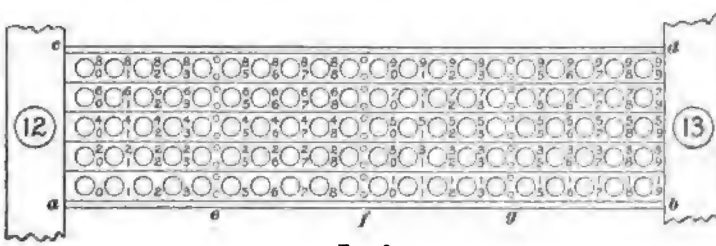


FIG. 8

jack of each strip. Instead of numbering the jacks in the vertical rows *e*, *f*, *g*, two small white dots are placed one above the other at the side of the jacks. These dots divide the bank of five strips into squares of five jacks each way and with the strips of white holly enable the operator to more quickly pick out the number of the multiple jack required. On the vertical strips, called *stile strips*, that divide the sections into panels, are located white number plates with the figures in black. These number plates, *12*, *13* designate the hundreds, and are located at the left and

in the center of each group of five rows of jacks. These numbers are duplicated in each section.

26. Size of Jacks.—The jacks were formerly made with a diameter of $\frac{7}{16}$ inch, the multiple jacks being mounted in hard-rubber strips, twenty in a row, spaced $\frac{1}{2}$ inch apart. The answering jacks were mounted in rows of ten per strip and the spacing was $\frac{7}{8}$ inch. The reason for the increased spacing of the answering jacks lies in the fact that the metal plate carrying the line number is placed beside the jack. Switchboards using this type of jack are constructed with seven jack-panels to a section.

About 1902, the size of the jack was reduced to $\frac{3}{8}$ inch with a spacing of $\frac{7}{16}$ inch for the multiple jacks and a spacing of $1\frac{3}{8}$ inch for the answering jacks. Using the $\frac{7}{16}$-inch jacks, the answering jacks are sometimes arranged twenty per strip with $\frac{1}{2}$-inch spacing. Under these conditions, the number plates are made smaller and placed as shown in Fig. 9. Switchboards using this type of jack are constructed with eight panels to a section. The number of answering jacks to be placed on a section will depend on the class of service and the capabilities of the operator. The safest way is to equip each section with a greater number of such jacks than can be handled, reserving the extra ones for spares. On a seven-panel switchboard, one hundred answering jacks to a panel is all that should be provided; while on an eight-panel board, ninety per panel will be sufficient to meet all requirements. The board shown in Fig. 7 has, for each operator's position, three panels of sixty answering jacks each, or one hundred and eighty jacks for each operator. All the service is measured in this case.

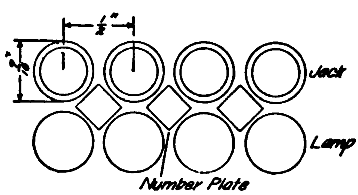


FIG. 9

27. Trunk Jacks.—Each row of outgoing multiple and common-trunk jacks is usually overlined with a white strip, called a *designation strip*, which consists of white strips of

paper held in place by nickel-plated clips fastened to the face of the board. Sometimes, these designation strips are placed vertically alongside the jacks, as shown in Fig. 7. On the designation strips are written the number of the trunk and the name of the exchanges with which they are connected.

28. On the keyboard shelf, as shown in Fig. 7, there are seventeen pair of plugs *D*, the corresponding supervisory lamps *E*, meter keys *F*, numbering plates *H*, combined listening and ringing keys *K*, order-wire keys *O*, and one master, selective, four-party ringing key *R*. By pressing any one of the four keys *R*, plus or minus pulsating currents may be supplied to either side of the ringing leads that run to all the regular ringing keys *K* in this one operator's position. To ring a party-line subscriber, the proper button of the master key *R* must first be depressed, and the regular ringing key in the row *K* then closed.

In many boards, especially where meter keys are not used, the row of keys shown at *F*, Fig. 7, is replaced by a row of keys like those shown in the row *K*. These keys at *F* may be used as individual-cord-circuit two-party-line selective-ringing keys, pulling the key in the forward position calling one party on the line, and pushing the key backwards calling the other party on the line, while one position of the keys *K* is used as a ring-back key, that is, to ring on the answering side of the cord circuit, and the other position of the keys *K* as a listening key; or the keys *F* may be used simply as ring-back keys.

29. Plugs.—In nearly all of the regular Bell central-energy switchboards, the tip of the plug is of small diameter compared with the sleeves, and resembles more a dull pin than the round end of the older type of plugs. The forward sleeve has, also, a diameter less than that of the rearward sleeve, or ring, as it is here termed. The two hard-rubber collars on either side of the sleeve are of a larger diameter, thus protecting the plug from making false contacts on its way into the jack.

30. A reflector runs all around the top of the board and contains, on its inner side, a number of electric incandescent lamps, which are used to afford light to the operators. The wiring for these lamps is carried in through bent tubes, which project from the top of the board. These lamps are

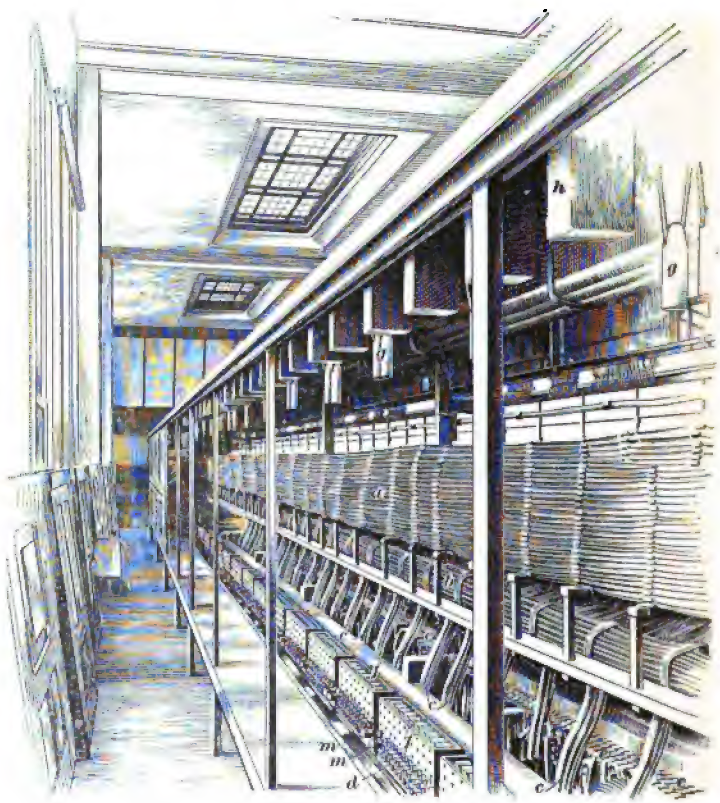


FIG. 10

so arranged that they throw light down on the operator's keyboard and sufficiently illuminate the multiple jacks to enable the operator to see the numbers thereon and yet not throw enough light on the answering jacks and line lamps to dim the latter. Placed in the face of the board, at some section, is a voltmeter which is used to test the insulation

of the lines. It is wired to a cord and plug placed on the keyboard; this circuit will be shown later in connection with the wire chief's duties.

31. In Fig. 10 is shown a rear view of a subscriber switchboard. The subscriber multiple cables are shown at *a*; the outgoing-trunk multiple cables at *b*; the answering-jack cables at *c*; the terminals to which the cord conductors are fastened at *e*; the 40-ohm and 80-ohm resistances in the subscriber operator's cord circuits, together with the resistances on the tone-test circuits, at *f*; and the supervisory relays at *d*. At *m*, *m*, at each end of each group of relays, are the two double-wound relays of the two tone-test circuits, and at *g* the brass weights on the transmitter cords of the operator's circuit are shown. Where breast-plate transmitter sets are used, these weights are not required. The condensers, induction coils, retardation coils, and local wiring are placed under the roof of the switchboard. The box-shaped projections *h* hanging from the roof are the repeating coils on the toll tone-test circuits $p' s'$ in Fig. 5.

32. Near the top of the cabinet on the chief operator's desk are the listening jacks arranged in four rows. The circuits from the switchboard and from the manager's and monitor's desks are connected to the two bottom rows and have designation strips placed above them.

33. The **toll board** contains rows of jacks associated with the toll trunks, outgoing ring-down and outgoing circuit trunks; these jacks are all equipped with designation strips. The answering jacks form the bottom row. In the same room, there is usually a monitor's desk and a manager's desk.

34. The **storage batteries** are placed in lead-lined tanks, the eleven cells in series giving a potential of 24 volts when charged and 22 volts when at the end of discharge. These batteries are encased in a wooden cabinet equipped with movable doors and a pipe to carry off the gases produced by charging. Four machines are provided

for furnishing the ringing current for the operators, and also the current for the disconnect signals on the outgoing trunks to magneto-offices. Two ringing machines also carry interrupters for the tone-test circuits. Two machines of each type are always furnished to provide for breakdowns.

35. Ampere-Hour Capacity.—The charging dynamo motor is one of the ordinary types of this machine, the motor side being wound to the required potential, while the dynamo side is wound to the potential of 26 volts and with an output, in amperes, depending on the size of the office. In ordering the storage-battery and charging equipment, it is well to look to the future and provide for an output about 50 per cent. in excess of that required when the exchange is opened.

The ampere-hour capacity of the battery cannot be accurately determined for any exchange, but the following figures will serve as a guide: for exchanges of 1,000 to 1,500 lines capacity, 1,000 ampere-hours; for exchanges of 1,500 to 2,000 lines capacity, 1,300 ampere-hours; for exchanges of 3,000 to 5,000 lines capacity, 2,000 ampere-hours; for exchanges of 5,000 to 9,000 lines capacity, 3,000 ampere-hours. The above estimate covers the total output of the batteries for the exchange, viz., transmission, lamp signals, ringing current, and trunk-signal machines.

Two charging machines should always be provided and should be run from independent sources of supply. For example, if the building in which the exchange is located is equipped with its own power plant, one charging machine should be designed to operate on this circuit and the other from an outside lighting or power circuit. In small exchanges of 1,000 to 2,000 lines, where the calling rate is not high and the cost of electric power is excessive, the regular charging machine should be run by some form of gas or oil engine, and the reserve machine should be run from the outside circuit. The object in having a reserve charging machine is to insure the possession of a charging current in case of accidents. It is not necessary to provide a reserve

battery, as the liability of the whole battery being thrown out of use by accident is very remote. In the event of an accident, only one cell will be disabled, and this can be cut out and repaired while the exchange is run on the remaining ten cells.

TESTS BY WIRE CHIEF

36. To properly understand the nature of the routine testing done by the wire chief, a thorough knowledge of the classes of trouble handled by him must be comprehended, for the testing done by him is in no way similar to that of locating faults in cables, or the usual acceptance tests, made in the majority of companies by the engineering departments.

The troubles encountered and cleared by the wire chief are of four kinds; viz., opens, short circuits, grounds, and crosses. The first class refers to the case when one or both sides of a circuit become discontinuous; the second refers to the case where both sides of a metallic circuit come into electrical contact; the third, where one or both sides of a metallic circuit come into electrical contact with the ground; the fourth, to the case where two circuits come into mutual contact. The first class of trouble has, for its result, the total cessation of conversation. The second class causes a cessation of conversation, although the tests show a closed line. The third class produces a noisy line, which may make conversation impossible; while the fourth class causes the conversation on one line to be heard on the other. The testing circuit used by the wire chief is so designed as to enable him to determine the nature of the trouble reported, and also to locate it in whatever portion of the line it exists, whether in the exchange apparatus, on the line, or at the subscriber's station.

THE WIRE CHIEF'S EQUIPMENT

37. The Wire Chief's Desk.—The wire chief's desk is provided with a long box-shaped cabinet extending along the top and equipped with the jacks on the testing trunks and talking lines to the switchboard and with order wires to

the operators seated at the first and last sections of the switchboard. Two voltmeters are connected to the testing circuits of the wire chief and his assistant. The testing trunks, talking lines to the switchboard, and order wires appearing on the wire chief's side of the desk are duplicated on the assistant's side; the testing circuits are independent. The rows of jacks and order-wire keys are equipped with designation strips.

38. The talking lines of the wire chief's desk are wired up in the same manner as the regular subscriber lines and are connected to drops and answering jacks at the switchboard in the usual manner. The testing lines consist of a jack at the wire chief's desk and a cord and plug at the switchboard, wired as shown in Fig. 11, where *a* represents the plug at the switchboard end of the circuit and *b*, the jack at the wire chief's desk.

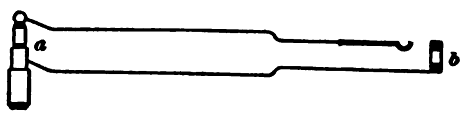


FIG. 11

The usual Bell practice is to have ten of these circuits wired to the first section of a switchboard, and twenty to the last section. Two order wires, as shown in Fig. 12, are bridged to the operator's telephones at the first and last sections, respectively, *a* representing the order-wire key on the

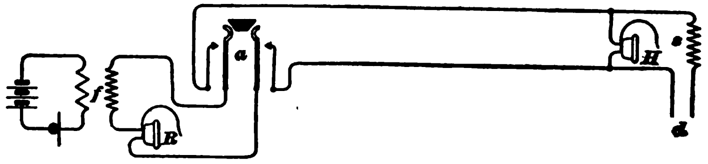


FIG. 12

wire chief's desk; *R*, his head-receiver, and *f*, the induction coil. At the other end, *H* represents the operator's head-receiver; *s*, the secondary of the induction coil; and *d*, the wires running to the listening keys.

The circuits to the main distributing frame are shown in Fig. 13. They consist of two jacks *J*, *K* wired together in such a manner that when a plug is inserted at *J* the circuit

toward K is opened at the points *1, 2*; and when a plug is inserted at K the circuit toward J is opened at the points *3, 4*. These jacks are placed on the wire chief's desk and are connected, respectively, to two jacks M, N, tip to tip and sleeve to sleeve, the jacks M, N being located at the main distributing frame.

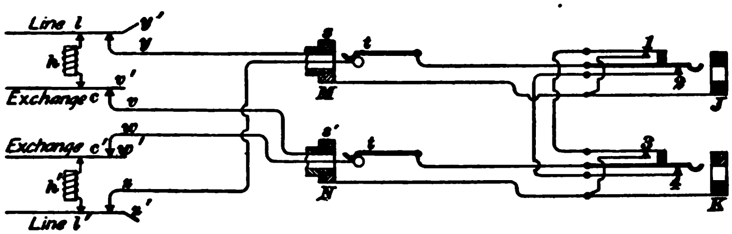


FIG. 13

39. To be used in connection with these latter jacks, a four-way cord with special plugs at both ends, as shown in Fig. 14, is provided. For insertion into the jacks J, K, a twin plug, consisting of two double plugs $s\,s'$ held rigidly together by the hard-rubber shell b, is used. For insertion between the springs on the main distributing frame, two detached plugs of hard rubber d, e are provided. Each has one corner beveled and covered with German-silver strips $y\,z$, so shaped as to

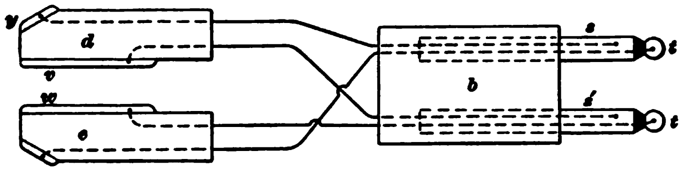


FIG. 14

slide under the heat-coil springs y', z', Fig. 13, on the main distributing rack, the heat coils h, h' being removed. The faces of the plugs opposite the two beveled sides are covered with two similar German-silver strips v, w, Fig. 14, that fit over the ground springs v', w', Fig. 13, on the main distributing rack. The clips y, z, Fig. 14, are connected to the sleeve s and tip t of one plug, while v, w are similarly connected to the sleeve s' and tip t' of the other plug.

If the heat coils *h*, *h'* are removed, and the detached plugs *d*, *e* are inserted in the main frame and the twin plug is inserted in the jacks *M*, *N*, the circuit may be traced from one outside line *l* through *y'–y–s–1–3–s'–v–v'*–exchange conductors *c*, *c'–w'–w–t'–4–2–t–z–z'*–line *l'*.

40. If the wire chief inserts the plug of his testing cord in the jack *J*, Fig. 13, the contacts *1*, *2* will be opened and the exchange end (conductors *c*, *c'*) of the line will be cut off. If, on the other hand, the test plug is inserted in the jack *K*, the contacts *3*, *4* will be opened and the outside end (line wires *l*, *l'*) of the line will be cut off. By this means, the wire chief is enabled to test the exchange and outside portions of the line independently of each other and to locate trouble in either branch. In exchanges in which the main distributing rack is far removed from the wire chief's desk, some special means of communication must be established between the two; this takes the form of a line wired to a jack on the wire chief's desk, and a telephone at the main distributing frame.

TEST CIRCUITS

41. In Fig. 15 is shown a testing circuit in which *a* is a plug wired to a reversing key *b*, through a 150-ohm telegraph sounder *S*, a dry battery *B* of about 40 volts, and a key *h* so connected that it will cut the battery in either metallic or to ground. A lower resistance sounder may be placed in a

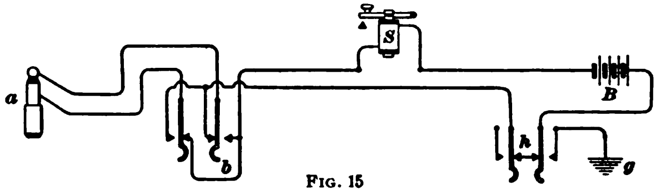


FIG. 15

local circuit controlled by a 150-ohm relay in the main circuit. The auxiliary testing circuit, shown in Fig. 16, consists of a plug *a* connected to a reversing key *w*, which grounds either the shank or the tip of the plug. This latter circuit is used to test crosses and its use will be presently explained.

42. With the exception of the trunks to the first and last sections of the switchboard and the wire-chief's testing circuit, the apparatus used in connection with the central-energy system is the same as that used with magneto-systems. In connection with the central-energy system, however, a more elaborate "layout" is employed. In Fig. 17 is shown the wiring of a testing trunk to the first and last sections of the switchboard. At *t*, *s*, *r* are shown the tip, sleeve, and ring terminals of the cord at the switchboard end. The wire running from the ring *r* passes through a 12-volt lamp *l*, two special opening-circuit keys *k*, *m* in series, one on the wire chief's and the other on the assistant's side of the desk, an 83⅓-ohm resistance coil and battery to ground. The wires from the tip and sleeve go through two cut-off jacks *n*, *o* in series, one on the wire chief's and the other on the assistant's side, to the line coil of the drop *d*. The armature of the drop is grounded and the contact is connected through a signal lamp to battery. This lamp is used as a signal instead of the shutter of the drop.

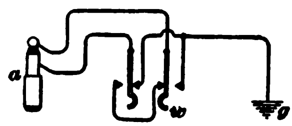


Fig. 16

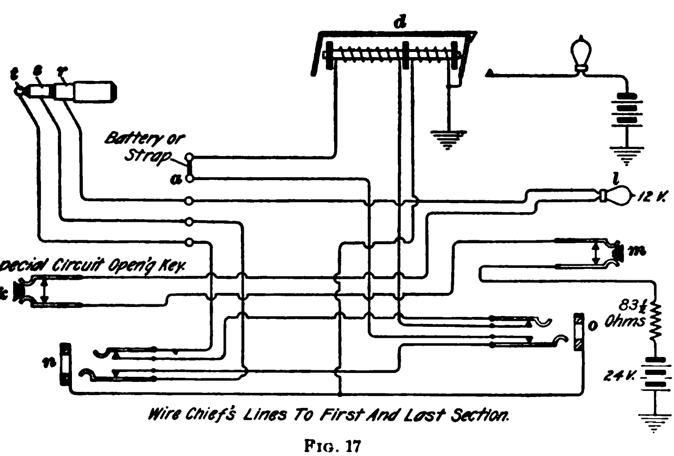


Fig. 17

When a line is taken up at the switchboard on one of these trunks, current from the battery flows through the two

circuit-opening keys *k*, *m*–the 12-volt lamp *l*–ring *r*–cut-off relay of the line so taken up to ground. The lamp *l* is lighted and notifies the wire chief that the connection has been made. The wire chief plugs into the jack *n* or *o* of the test trunk with the plug *P*, Fig. 18, of his testing circuit, and by depressing either of the circuit-opening keys *k*, *m* restores the cut-off relay on the subscriber's line and lights its line lamp. Then, by listening for the operator to answer, he is enabled to determine the condition of the line-lamp circuit. This is very useful in making a thorough test on subscriber lines.

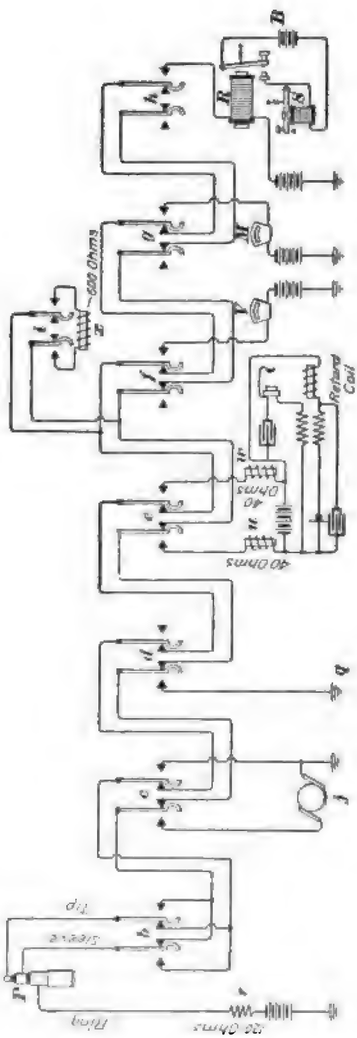


Fig. 18

43. In Fig. 18 is shown **the wire chief's testing circuit.** It consists of a plug *P*, the sleeve and tip of which are connected with eight keys. The first key *b* is simply a reversing key. The second key *c* is the ringing key, the ringing current generator being shown at *j*. The third key *d* is a grounding key, which is used to ground one side of the line at *q*; to ground the other side, close both *b* and *d*. The fourth key *e* is the listening key and serves to cut in the wire chief's listening and talking circuit, and also to

supply the transmitter, at the distant end of the line, being tested, with current from the battery through the retardation coils u, w. The fifth key i is used to hold the line by bridging across it the 600-ohm impedance coil x; it is used by the wire chief when he is interrupted in testing and compelled to talk on some other circuit. The sixth key f inserts the voltmeter V with the 24-volt common battery in series in either side of the line, depending on the position of key b. The seventh key g inserts in one side of the line the milliammeter M, which may merely consist of a second coil and scale on the voltmeter V. The last key h inserts a 150-ohm telegraph relay R and battery in one side of the line, the relay controlling a telegraph sounder s, which, if 4 ohms is in resistance, will require two or three dry cells at B.

It should be remembered that all lines, both subscriber lines and circuit trunks, are normally open on central-energy systems; whereas, on magneto-systems, they are normally closed. Therefore, in testing in central-energy systems for grounds and opens, a test must be made first on one side of the line and then on the other. The voltmeter is used in testing grounds, while the milliammeter is used for indicating short currents or crosses by measuring the line resistance.

METHOD OF USING TESTING CIRCUITS

44. Testing Open Circuits.—In describing the methods employed to test for the various classes of troubles, a sample case will be taken for each class and the necessary work described in detail. The case of an **open circuit** will be considered first. This trouble makes itself known to the traffic department, from the fact that the subscriber or the distant exchange, in the case of a trunk, cannot be raised. It is then reported to the wire chief, whose first duty in testing for a trouble of any nature whatever is to determine its location. He must ascertain whether it is inside the exchange and within the jurisdiction of the inside troubleman, or without the exchange and within the jurisdiction, therefore, of the outside troubleman or inspector.

If in the exchange, he must determine whether it is between the main and intermediate distributing frames, in the answering-jack cable, or in the multiple cable. On account of economy of time, the test is always started at the last section of switchboard; and the wire chief therefore goes in on the order wire, Fig. 12, to the operator at the last position, and orders up the line to be tested, on one of the testing-trunk plugs, Fig. 11 or 17, to that position. The operator, in question, thereupon inserts the plug of the testing trunk assigned into the multiple jack of the line to be tested. The wire chief inserts the plug *a*, Fig. 15, of his testing circuit into the jack of the testing trunk (*b*, Fig. 11, or *n*, Fig. 17) and adjusts the key *h*, Fig. 15, so as to cut the battery *B* in metallic, that is, in series with the two sides of the circuit. If the line is open, no current will flow through the sounder *S* and it will fail to click; the line in trouble is then ordered up and tested at the first section. Obviously, if the "open" lies in the multiple between the first and last sections, the line will test "closed" when taken up at the first section, and this condition will be announced by the clicking of the sounder. If the line tests open when taken up at the first section, the trouble lies beyond this point.

45. The next step is to direct an inside troubleman to short-circuit the line at the lugs on the intermediate distributing frame while the test circuit is still connected at the first section. If the trouble lies in the bridging cable between the first section and the intermediate frame, the sounder armature will fail to click. If the trouble shows beyond this latter point, the test is made at the main distributing frame, using the circuit shown in Fig. 13 and the cord and plugs shown in Fig. 14, removing the heat coils from the arrester springs, inserting plugs *d* and *e* in their places and the plugs *s* and *s'* into the jacks *M*, *N*. The wire chief, by inserting the plug of the testing circuit (Fig. 15 or Fig. 18) into the jack *J*, Fig. 13, tests the line from the main distributing frame outwards, cutting off the end toward the switchboard. On the other hand, by inserting the test plug into jack *K*, the section

of the line toward the switchboard is tested, the outside section being cut off. If the circuit proves to be all right to the lugs on the intermediate distributing frame, but tests open when taken up at the main frame and tested inwards, the trouble is between the two frames. If, on the other hand, the line proves to be all right inwards, the trouble is between the main frame and the subscriber station. If the trouble exists in the answering-jack cable, the line will test all right from the last section of the switchboard and the wire chief will be able to raise the subscriber. In this event, the wire chief will direct an inside troubleman to call the subscriber from the answering jack, whereupon the trouble will have been detected. It should be remarked that the troubleman, in assisting the wire chief, should always keep a sharp lookout for loose soldering, broken wires, and the like. Whenever heat coils are removed, they should always be tested before replacing.

46. Should the trouble be located outside, it will be assigned to an outside troubleman, who will proceed to the underground cable box, bridge in on the line, and ring. If the operator answers, but the subscriber remains silent, he knows that the trouble lies between the cable box and the subscriber's telephone. His next duty is to thoroughly inspect the line between these two points and locate the trouble. Should the trouble be situated between the cable box and the exchange, the wire chief is informed and a new assignment of cable conductors is obtained for this line from the construction department. When this has been obtained, the wire chief informs the troubleman, who makes the necessary change at the cable box while the necessary change in cross-connections is made on the main frame by the inside troubleman. This work being completed, the outside troubleman again calls the wire chief, who makes a final test and informs the troubleman that the line is all right.

The necessary steps to be taken in testing and clearing a line that is open have thus been followed. In treating the other classes of trouble, whenever the methods are the same

as those described, they will only be alluded to. Only the distinctive features will be described in detail.

47. Grounded Lines.—When testing a grounded line, it must be remembered that, while an open line tests all right on either side of the break, a grounded line tests "in trouble" throughout its entire length, no matter from what point it may be tested. Therefore, to locate trouble of this nature, successive portions of the line must be cut off and tested out independently. For this reason, the first test made on this class of trouble is made at the main distributing frame, using the circuits shown in Figs. 13 and 15. The key *h* of the wire chief's testing circuit, Fig. 15, is thrown so as to connect one side of the battery to ground. The testing circuit under these conditions runs from the ground *g*, through the battery *B* and sounder *S* to one side of the line, the return circuit being made through the ground causing the trouble. Since the line is a closed metallic circuit, the sounder will click, no matter in what position the reversing keys are placed. Suppose that, when making the test, the ground shows within the exchange, the testing circuit, including the sounder, will include one side of the line to the grounded point, or the other side of the line, through line drop and back on the opposite side of the line to the grounded point, depending on the position of the reversing key. In the one case, the resistance of the portion of the line, including the sounder, is so small that this portion of the circuit may be considered as grounded direct. In the other case, the current includes the line drop, which has a resistance of about 600 ohms. The difference in the two conditions can be detected by the difference in the resistance of the lever of the sounder to a force applied to separate the armature from the cores, for which purpose one finger may be used. This difference in pull is of valuable assistance in locating a ground.

48. The ground being located in the exchange, the conductors in the answering-jack cable are disconnected at the main distributing frame. If the trouble is still present, the conductors in the multiple cable are disconnected. If the

trouble fails to disappear, it is located between the two frames. Should the trouble be located in the multiple, the inside troubleman makes an inspection of every jack on the line. To do this work, he often has to wedge apart the layers of multiple cable to get at the jack in question. For this purpose, he uses two hardwood right-angle wedges about 1 inch thick and having a hypotenuse about 15 inches long. Should the trouble be located outside the exchange, the reversing key *b*, Fig. 15, is used to determine the side of the line in trouble and if one side of the line tests "dead grounded," the assumption is made that the trouble lies in the carbons of the lightning arrester. The inside troubleman cleans these carbons to free them from carbon dust that often collects, and in 80 per cent. of the cases reported the trouble will be remedied.

Should the trouble be located beyond the main frame, the outside troubleman is called into action. He performs his work as already described, except that he opens the line at the cable terminal before calling the wire chief for a test. A short circuit is located in the same manner as a ground, except that the battery of the testing circuit, Fig. 15, is cut in metallic.

49. Crosses.—In testing crosses, the auxiliary testing circuit, shown at Fig. 16, is used. A **cross** may be defined as the making of an electrical contact between one or both sides of two metallic circuits. A cross makes its presence known by the fact that conversation held over one line can be heard on the other. This class of trouble should not be confused with "cross-talk," which phenomenon is the result of induction between two circuits. The work of testing a cross consists of locating the point of contact in question. The two lines in trouble are taken on two testing trunks and into the jack of one trunk is inserted the plug *a* of the testing circuit, Fig. 15, and into the jack of the other trunk is inserted the plug *a* of the auxiliary testing circuit, Fig. 16.

50. Let *a*, *b*, Fig. 19, be a pair of line wires with a telephone at *m*, and *c*, *d* be another pair of line wires with a

telephone at *n*. Let *x* denote the cross. Let *f* be the plug, *S* the sounder, and *B* the battery of the testing circuit, Fig. 15, grounded at *e*, and *h* be the plug of the auxiliary testing cir-

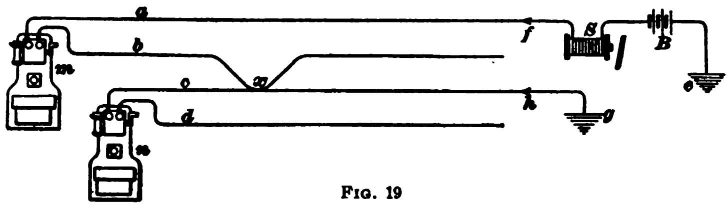


FIG. 19

cuit, Fig. 16, grounded at *g*. A circuit will be formed from the battery *B* through the sounder *S*–line *a*–instrument *m*–line *b*–cross *x*–line *c*–*h*–*g*–*e*. This circuit passes through the bell coils at *m* and therefore has an appreciable resistance. If,

1. Message rate—private line
2. Message rate—party line
3. Flat rate—private line
4. Flat rate—party line
5. Pay station—private line
6. Pay station—party line
7. Automatic pay station
8. Message-rate and pay-station party-line

FIG. 20

by means of the reversing key, the battery is sent out on the sleeve of the plug along *b*, it will reach the cross *x* without passing through the bell coils, and practically a short circuit

will be formed, which can be detected by the increased pull on the armature of the sounder.

51. In Fig. 20 are shown the various symbols used on the caps of the line lamps to denote the kind of service furnished on each line. This assists the operator where she has two or more kinds of service to care for. The more kinds of service the operator has to attend to, the slower becomes the service and the greater the number of errors made.

KELLOGG CENTRAL-ENERGY SYSTEM

CENTRAL-ENERGY MULTIPLE-SWITCHBOARD SYSTEM

SUBSCRIBERS' TELEPHONES

1. Theoretical Circuit.—The **central-energy multiple switchboard** made by the Kellogg Switchboard and Supply Company is now used in many large exchanges. But as it is constantly being improved and changed to suit local conditions all its modifications cannot be described here. The systems herein given, however, represent the most modern and largest installations.

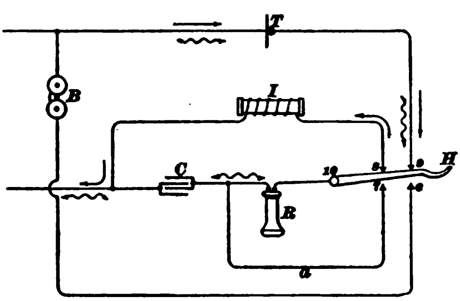


FIG. 1

The connections of the Kellogg subscriber's central-energy telephone is shown in Fig. 1, in which *B* is a 1,000-ohm bell; *C*, a 2-microfarad condenser; *R*, a 70-ohm double-pole receiver; and *I*, a 25-ohm impedance coil. When the receiver rests on the hook, it is short-circuited by the wire *a*, while the bell *B* and condenser *C* are connected in series, through contacts *6* and *7*, across the two line wires; this condition is shown in Fig. 2 (*a*). The ringing currents

can pass through the bell and condenser readily enough to ring the bell, but they will not pass through the receiver because it is short-circuited.

When the receiver is off the hook, the condition is shown in Fig. 2 (*b*), in which the receiver *R* and condenser *C* are in

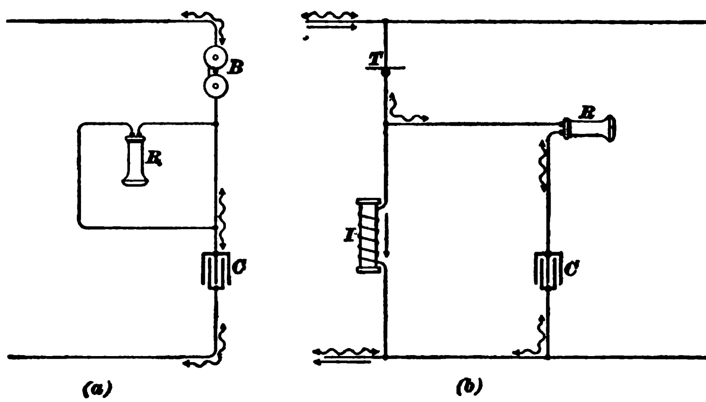


Fig. 2

series and in parallel with the impedance coil *I*; the transmitter *T* is in series with the two parallel circuits. The impedance coil *I* opposes the passage of the rapidly fluctuating voice currents and the condenser *C* opposes the passage of the steady direct current from the exchange storage battery. The path through the transmitter and impedance coil, being of suitable resistance, readily allows sufficient current to flow from the exchange battery to operate the transmitter, and the condenser in the second path allows only the high-frequency voice currents to flow through the receiver. The transmitter possesses no inductance, hence the voice currents reach the receiver without passing through any inductive resistance.

2. The receiver will be comparatively quiet, even if the subscriber places it to his ear while the operator is applying ringing current to the line, because the ringing current, being of low frequency, more readily passes through the retardation coil than through the condenser and receiver. A subscriber

may attract the operator's attention, without causing any disagreeable sounds in his receiver, by working the hook switch up and down, and thus flashing his supervisory lamp. The springs of the hook switch are given such a normal trend or bias that, when the lever is depressed, contacts *8* and *9*, Figs. 1 and 3, do not separate from contact *10* until after the latter engages contact *7*. The effect of this is to complete a shunt around the receiver for the flow of the extra current due to the breaking of the circuit. In the same manner, the spring *7* is adjusted to separate from *10* only after contacts *8* and *9* are made. This subscriber's circuit may be used successfully in connection with any ordinary central-energy switchboard operating with from 20 to 50 volts.

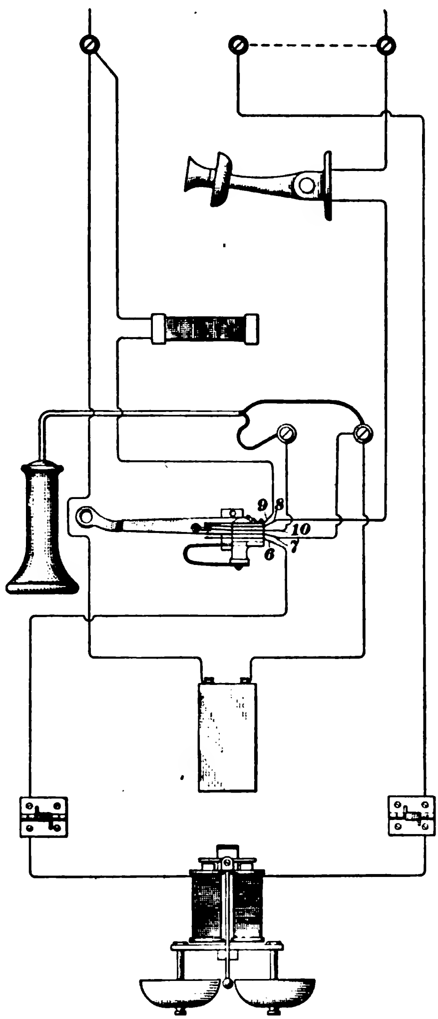


FIG. 3

3. The **No. 9-A retardation coil** used in the Kellogg central-energy subscriber's telephone consists of a spool having a core ¼ inch in diameter, made of No. 26 annealed-iron wires inserted in a paper tube; the spool heads

are made from maple and are 1 inch square and $\frac{3}{8}$ inch thick. When assembled, this spool has a winding space $2\frac{3}{4}$ inches long, but its full length is $3\frac{1}{2}$ inches. The winding consists of 3,192 turns of No. 27 single, silk-covered, copper wire wound in nineteen even layers, giving a resistance of about 25 ohms.

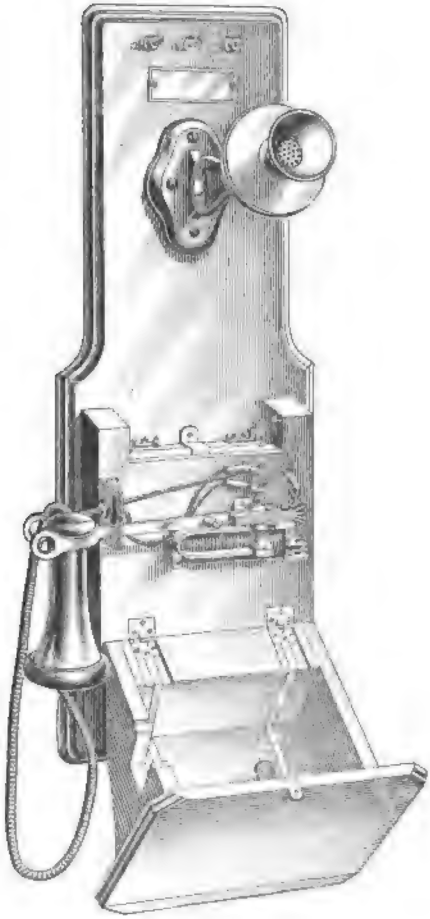


Fig. 4

4. The **Kellogg central-energy wall telephone** is wired as shown in Fig. 3, while Fig. 4 is a view of the instrument with the case opened. All connecting wires are tinned copper, soldered at joints, and, as far as possible, run in grooves in the backboard and covered with wax, which prevents the exposed woodwork from absorbing moisture and perhaps causing a leakage of battery current. Where exposed, the wires are insulated with a braiding of cotton. The bell is mounted in the hinged portion of the case, the wiring being transferred to it through hinges that have flexible spiral springs, the ends of which are riveted and soldered to the halves of the hinge, thus insuring good connections. The circuit is run from the hinges to the bell with tinned copper ribbon. The two sides of the transmittter circuit are led

through the hollow transmitter arm and out through the back-board with lamp cord; the arm itself is not used as one conductor. The condenser is placed in a cavity behind the switch-hook and impedance coil. The instruments are made with either exposed or concealed binding posts, the latter being placed under the hinged shelf. All instruments are equipped with three binding posts, the middle one to be connected to the ground on two-party selective lines. On individual lines, the middle and right-hand posts, as one faces the telephone, should be connected together by a wire.

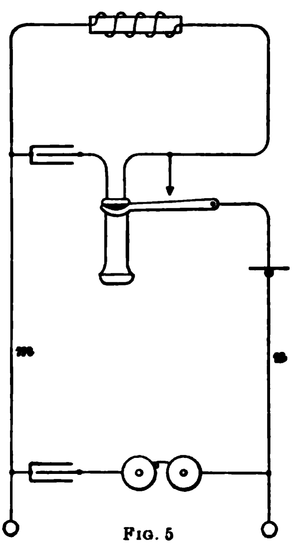


Fig. 5

Wooden washers, one over each of the four mounting screws, hold the telephone far enough from the wall to make room for the line wires and protect the telephone against any dampness in the wall.

5. Two condensers are used in the **Kellogg central-energy desk-set connections**, shown in Fig. 5, to reduce the number of wires between the desk stand and the bell box, which contains the bell and one condenser, to two, *m* and *n*; and to reduce the contacts controlled by the hook switch in the desk stand, where there is no space to spare, to the least number possible, in this case one.

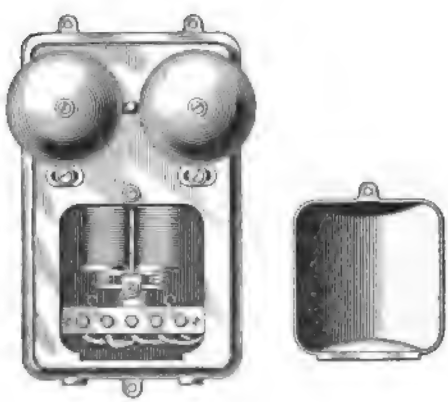


Fig. 6

6. The **Kellogg desk-set box,** which contains a bell and condenser, is made with either a wood or an iron case. The wooden desk-set box has a 2-microfarad condenser, but the iron desk-set box, shown in Fig. 6, has a 1-microfarad condenser. The iron desk-set box is compact, occupying a wall space 5 inches by 7½ inches, and has front and back enclosing lids, which, when removed, expose the bell, condenser, and connecting rack. The bell is ordinarily wound to have a resistance of 1,000 ohms.

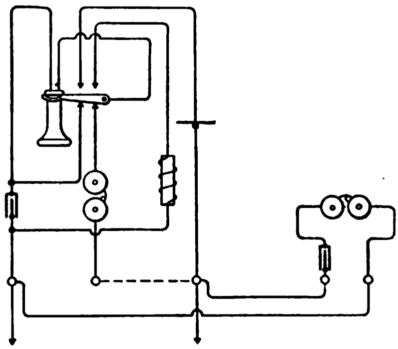


FIG. 7

A desk-set box that is used on individual and two-party lines has five binding posts, three for the line and ground connections and two for the desk-stand cord. When used for individual-line service, the sleeve and ground binding posts should be connected together. The type for individual-line service only has four binding posts, two for the line wires and two for the desk-stand cord.

These desk-set boxes are also used as **extension bells,** which are connected to a Kellogg wall telephone as in Fig. 7.

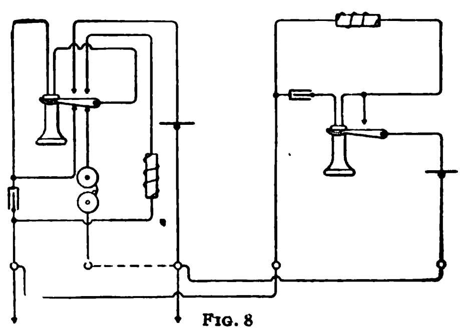


FIG. 8

7. An **extension desk set** is connected to a Kellogg central-energy wall telephone by being bridged across the line binding posts of the wall telephone, as shown in Fig. 8. A bell, which the exchange operator can ring, is usually provided only at the wall telephone, but the exchange can be called from either telephone.

Fig. 9 shows the wiring when a single desk telephone is to be used from any one of several points about a house or restaurant. The extension bell *a* is placed at any convenient point from which it may be heard all over the premises or where incoming calls are to be answered. The line is then connected to spring jacks *j*, *j* at the several points from which it is desired to talk. A plug *p* is fitted to the end of the desk-stand cord and the telephone may be connected through this plug and any jack to the line circuit.

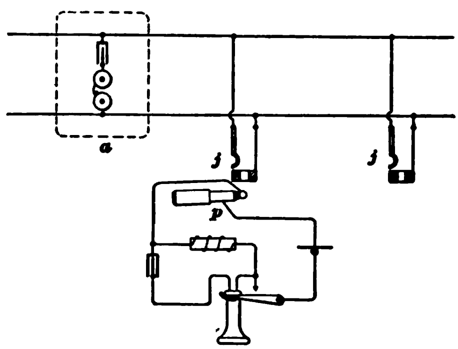


FIG. 9

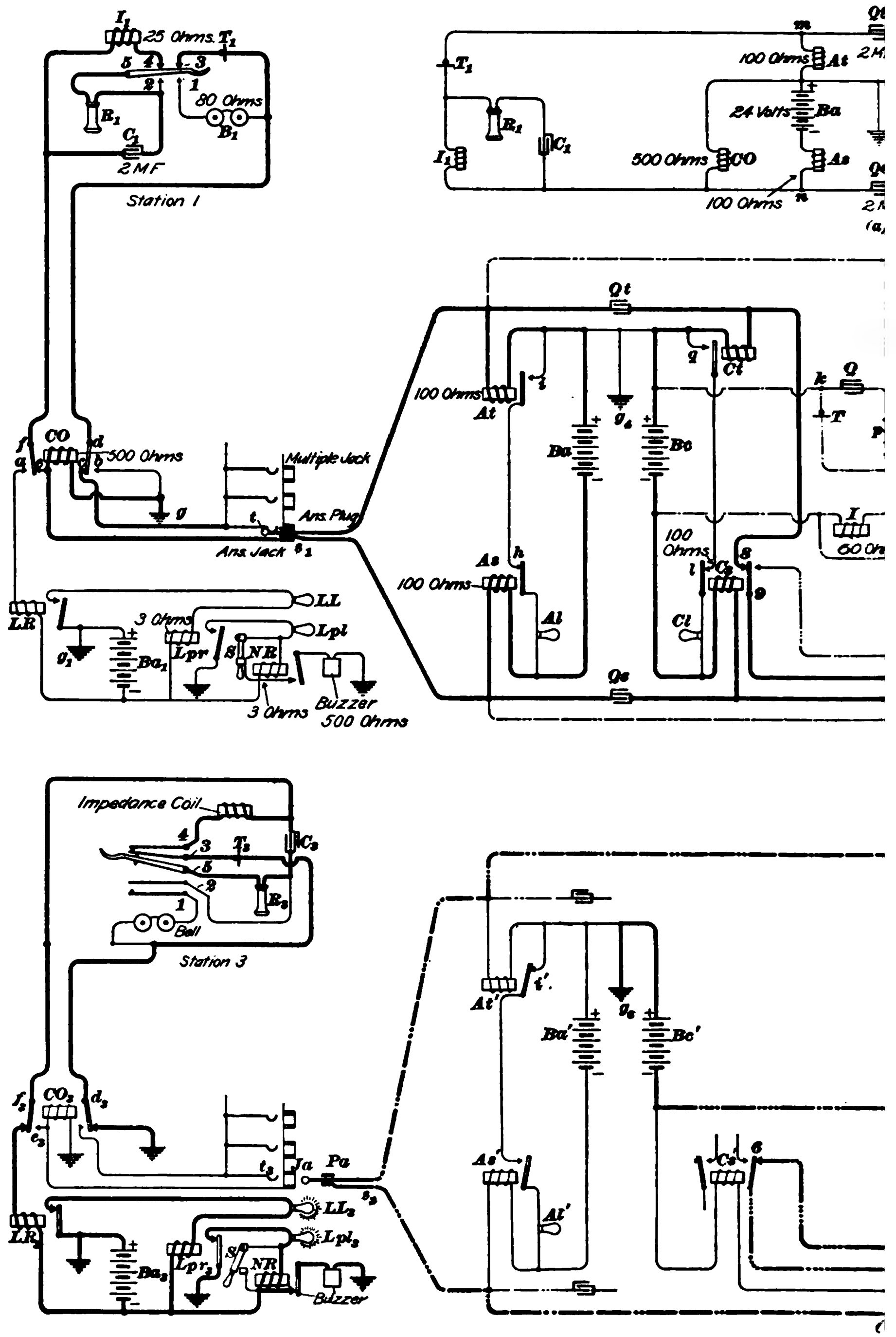
CENTRAL-ENERGY MULTIPLE SWITCHBOARD

8. Kellogg Jacks, which are very simple, have but two contacts and are the smallest made, having been mounted with only $\frac{3}{16}$ inch between centers of jacks on the multiple section; in fact, up to 1905, certain Kellogg switchboards contained more multiple jacks in a given space, within the reach of one operator, than boards made by any other company. The line circuit, as a whole, is quite simple, but the operator's cord circuit is rather complicated, there being four relays, an extra winding on the operator's induction coil, a test relay common to each operator's position, and a slightly complicated test-and-listening key in addition to the ringing key. The arrangement of circuits, if there were not so many relay contacts, is good, the transmission is satisfactory, and the various devices are well designed and constructed.

To simplify the connections, it will be advisable in many figures to show several batteries, but it should be remembered that in any one Kellogg exchange only two batteries are required.

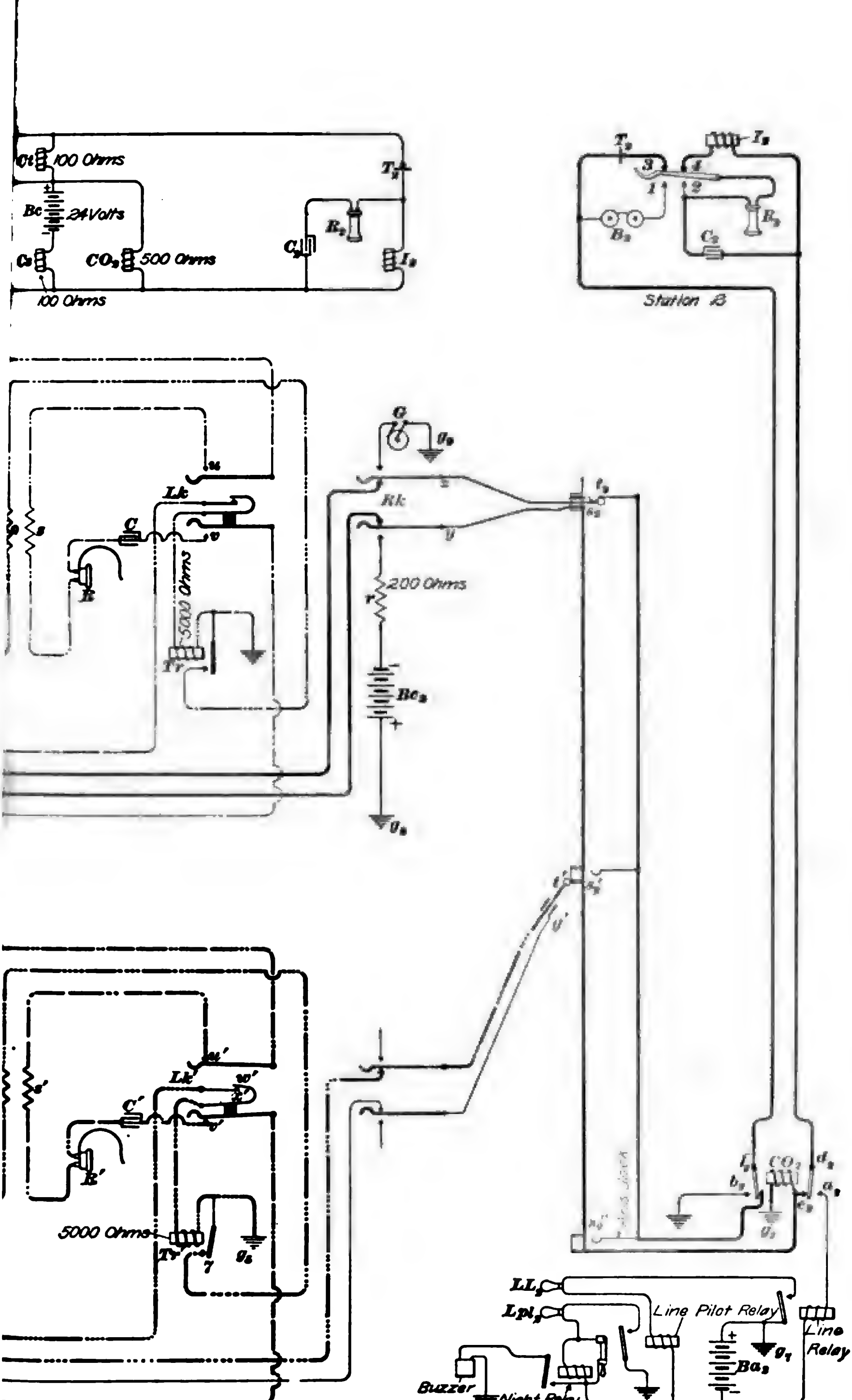
9. Transmission Circuit.—The circuit between two subscribers, while holding a conversation, is shown in Fig. 10 (*a*). The storage battery *Ba* supplies current for the relays and subscriber's instrument on the answering side, and the storage battery *Bc* for the same apparatus on the calling side of the circuit. These two batteries supply all the line and cord circuits. *At* and *As* are supervisory relays in the answering side, while *Ct* and *Cs* are supervisory relays in the calling side of the same cord circuit; *Co* and Co_1 are the line cut-off relays. *At*, *As*, *Ct*, and *Cs* act in very much the same manner as the impedance, or choke, coils in the Stone central-energy method, except that the answering and calling sides are supplied with current from separate batteries and coils, condensers *Qt*, *Qs* being used to connect the two sides together. The fact that one line may be much longer and of a much higher resistance than the other has very much less influence on the transmitting qualities of the system than would be the case with the simple Stone arrangement. The voice currents can readily pass from one side to the other through the condensers *Qt* and *Qs*, which have a capacity of 2 microfarads each.

When the subscriber's receiver is on the hook, the bell and condenser are connected in series across the two line wires; when the receiver is removed from the hook, the battery current flows through the impedance coil and the transmitter. When talking into the transmitter T_1, its variation in resistance produces a variation in the difference of potential between the points *m*, *n*, thereby varying the charge in the condensers *Qt*, *Qs*, which in turn causes a variation of the charge in the condenser C_2. This causes a variable or fluctuating current to flow through the receiver R_2. Thus the high-frequency talking currents are said to pass more readily through the condenser and receiver than through the impedance coil. This arrangement gives very satisfactory results and, it is claimed, does not produce so strong side tones as the arrangement used by the Bell Telephone Company. The condenser in the subscriber's telephone is also said to improve the quality of the tone, making it clear and sharp by



KELLOGG CENTRAL-ENERGY SU

FIG



IBER, LINE-AND-CORD CIRCUITS

reenforcing the higher tones, which are rather weak, and cutting down the lower tones, which are, relatively, too strong.

The rapidly fluctuating voice currents do not pass through any of the relays, which are iron clad or provided with good magnetic circuits of iron and enclosed in metal shells, because of their high impedance. Although it might appear that *A t* and *C O* short-circuit the line, it must be remembered that the impedance of the 500-ohm cut-off relay *C O* is very great for the very rapidly fluctuating voice currents. As the relay *C O* takes some of the battery current that passes through the relay *A s*, the relay *A t* gets less current than the relay *A s*; consequently, the relay *A t* must get sufficient current and the relay *A s* more than sufficient current to operate it. This is no great disadvantage, as considerable margin must be allowed for these relays anyway, since the resistance of the line circuits varies considerably.

The resistance of Kellogg transmitters has been arranged to suit various conditions. For use with 24 and 48 volts, the transmitters usually have a resistance of about 100 ohms; for lines of higher average resistance, the transmitter resistance has been made about 200 to 300 ohms, as in Buffalo, New York; while for lines having a still higher resistance, a special 600-ohm transmitter has been made.

10. Line and Cord Circuits.—In Fig. 10 (*b*) are shown three subscribers' instruments and their line circuits; also, one complete operator's cord circuit and enough of another cord circuit to explain the busy test. Since the positive terminals of the batteries are grounded, every circuit that is connected directly to the positive terminal of either battery can be represented as grounded, as this simplifies the connections and is customary. The wiring and operation of the subscriber's instrument at station *3* are exactly the same, in principle, as at stations *1* and *2*, but the spring contacts at station *3* are arranged to more closely resemble the actual instrument.

OPERATION OF SWITCHBOARD CIRCUITS

11. Answering a Calling Subscriber.—The springs f, d, Fig. 10 (b), normally rest against contacts a, b. When the subscriber at station *1* removes the receiver R_1 from the hook, enough current flows through $B a_1–g_1–g–b–d–T_1–3–4–I_1–f–a–L R–B a_1$, to close the line relay $L R$, thereby lighting the line lamp $L L$ and closing the line-pilot relay $L p r$, which, in turn, causes the line-pilot lamp $L p l$ to light. If the night relay $N R$ is not short-circuited by the switch S, this relay will close and cause the buzzer to sound. The line circuit for station *3*, in the lower left-hand corner, is shown in this condition, that is, when the receiver R_3 is off the hook but before the operator has inserted an answering plug in the answering jack. There is only one line-pilot relay $L p r$ and one line-pilot lamp $L p l$ for each operator's position and one night relay $N R$ and one buzzer for the entire switchboard.

The operator, seeing that the line lamp $L L$ is lighted, inserts an answering plug in the answering jack, which is directly above the line lamp of that line. Current now flows through $B a–g_4–g–C O–s_1–A s–B a$, thereby closing the cut-off relay $C O$, which cuts off the line relay $L R$ by opening its circuit at a, and causes both the line and line-pilot lights to go out. Current now flows through

$$B a–\left\{\begin{matrix} g_4–g–C O \\ A t–t–c–d–T_1–3–4–I_1–f \end{matrix}\right\}–e–s_1–A s–B a$$

thereby closing both the tip and sleeve supervisory relays $A t$ and $A s$, respectively, on the answering side of the cord circuit. This closes the lamp circuit at h, but opens it at i and, hence, the answering supervisory lamp $A l$ does not light.

The operator, having closed her listening key $L k$, can converse with the subscriber. When she speaks into her transmitter T, its variation in resistance produces a variation of potential between the points j and k, thereby causing the charge on the condenser Q to vary, and the flowing in and out of this charge through the winding p induces in the winding s an alternating current that flows through $u–t–c–d–T_1–3–5–R_1–C_1–f–e–s_1–v–C–R–s$, thereby reproducing her speech at

the subscriber's receiver R_1. When the subscriber talks into his transmitter the fluctuating currents produced affect the operator's receiver R.

12. Connecting Calling to Called Subscriber.—If subscriber *1* calls for subscriber *2*, the operator first makes the busy test, as in other multiple systems. As this can be more easily explained a little later, let it be supposed that line *2* is not busy and that the operator, therefore, inserts the calling plug into the jack. While doing this, she restores the listening key Lk to its normal position. Enough current can now flow from $+Bc$ through g_4–g_3–CO_2–s_2–y–Cs–Bc to close both the calling sleeve supervisory relay Cs and the cut-off relay CO_2, and this current through the sleeve conductor makes the jack-sleeves s_2'', s_2' of this line busy if tested at any other section of the board. The closing of the cut-off relay CO_2 opens the circuit of the line relay at a_2 and thus prevents the lighting of the line lamp LL_2. The closing of the circuit at l by the supervisory relay Cs causes the calling supervisory lamp Cl to light, for this circuit remains closed at q, because the relay Ct is not energized as long as subscriber *2* allows his receiver to remain on the hook, since no battery current can flow from $+Bc$ through the relay Ct, in the circuit 8–9–z–t_2–f_2–B_2–1–2–C_2, as the condenser C_2 is equivalent to a break in a battery circuit.

When the operator closes the ringing key Rk, current flows from $+Bc_2$ through g_9–g_8–CO_2–s_2–y–r–Bc_2, thereby holding the cut-off relay CO_2 closed, which is necessary in order that the ringing current may flow from the alternating-current ringing generator G through z–t_2–f_2–B_2–1–2–C_2–d_2–e_2–s_2–y–r–Bc_2–g_8–g_9, and thus ring the subscriber's bell B_2. Practically, the only opposition offered to this alternating current by the battery Bc_2, through which it flows, is that due to the internal resistance of the battery, which is very small. Moreover, since the battery current cannot flow through the subscriber's condenser and bell, the alternating current flowing through the bell is practically not influenced by the presence of the battery at all. The ringing key opens when released.

13. Completed Connection and Disconnection.—As soon as the receiver R_2 is lifted off the hook, which is the condition represented in this figure, current flows through Bc–Ct–8–9–z–t_2–f_2–T_2–3–4–I_2–d_2–e_2–s_2–y–Cs–Bc, thereby closing the calling tip supervisory relay Ct, which makes the calling supervisory light Cl go out because its circuit is now open at q. Subscribers *1* and *2* can now converse over the circuits, as shown in Fig. 10 (*a*).

As soon as either subscriber replaces his receiver on the hook, the battery circuit through his telephone will be opened and, consequently, the corresponding supervisory relay (At or Ct) in the tip side of the cord circuit will release its armature, thereby opening (at i or q) the circuit of the corresponding supervisory lamp (Al or Cl). As each lamp lights, the operator removes the corresponding plug from the jack.

14. Busy Test.—Assume that subscribers *1* and *2* are connected through a cord circuit, as shown in Fig. 10 (*b*), with their receivers on or off their hooks, and that subscriber *3* wishes to talk with subscriber *2*. When he removes his receiver R_3 from the hook, his line circuit is in the condition shown in the lower left-hand corner of Fig. 10 (*b*), the line, line-pilot, and night relays being closed, the line and line-pilot lamps lighted, and the buzzer circuit closed. The operator at this section inserts an answering plug Pa in the answering jack Ja, which causes relays CO_3, At', and As' to attract their armatures and relays LR_3, Lpr_3, and NR to release their armatures; consequently, the buzzer circuit will be opened and the lights LL_3 and Lpl_3 will go out. The supervisory lamp Al' will not light because its circuit will be open at i'. The operator also closes her listening key Lk', obtains the number of the subscriber desired, and proceeds to make the busy test on line *2*. With the answering plug Pa in the answering jack Ja, the relays in the positions mentioned, the listening key Lk' closed, and all other connections involved as shown in this figure, the operator makes the busy test by touching the tip t' of the

calling plug against the sleeve contact s_2' of the jack in her section belonging to subscriber *2*. Since the sleeve y' of the plug is open, no current flows through the calling-sleeve-supervisory relay Cs' and its armature rests against the contact *6*. Since line *2* is busy, current flows through Bc–g_4–g_5–Tr'–x'–w'–6–t'–s_2'–s_2–y–Cs–Bc, thereby closing the test relay Tr' and allowing current to flow from $+Bc'$ through g_4–g_5–7–o' to $-Bc'$. The first rush of this current through the winding o' of the operator's induction coil induces, in the winding s', a current that charges the condenser C', which is in the circuit R'–s'–u'–t_3–d_3–T_3–3–5–R_3–C_3–f_3–e_3–s_3–v'–C', thereby producing the ordinary busy-test click in the operator's receiver R'; a click will also be made in the waiting subscriber's receiver R_3.

If line *2* is not busy, s_2' will have the same potential as the ground, because it is connected through CO_2 to g_2, a circuit in which there is no current, and, therefore, there will be no tendency for any current to flow through the test relay Tr'; hence, contact *7* will not be closed and no current can flow through o', consequently no current is induced in s'. The contacts w', x' in the listening key serve to cut off the common test-relay circuit from the individual cord circuits so that trouble in any one cord circuit, which would otherwise make the test inoperative, will not affect the operator's entire position. These contacts were not originally considered necessary, but later they had to be added for this reason. There is but one test relay for each operator's position.

Although a subscriber may have removed his receiver from the hook, his line will not test busy until a plug is inserted in one of the jacks belonging to his line.

15. A subscriber-operator's cord circuit, so called because it is used only for the direct connection of two subscriber's circuits, and not for the connection of toll or trunk circuits, is shown in Fig. 11. It is also frequently termed a *local cord circuit* or an *A operator's cord circuit* and is the same as the cord circuit shown in Fig. 10, with the addition of some details omitted in that figure in order to

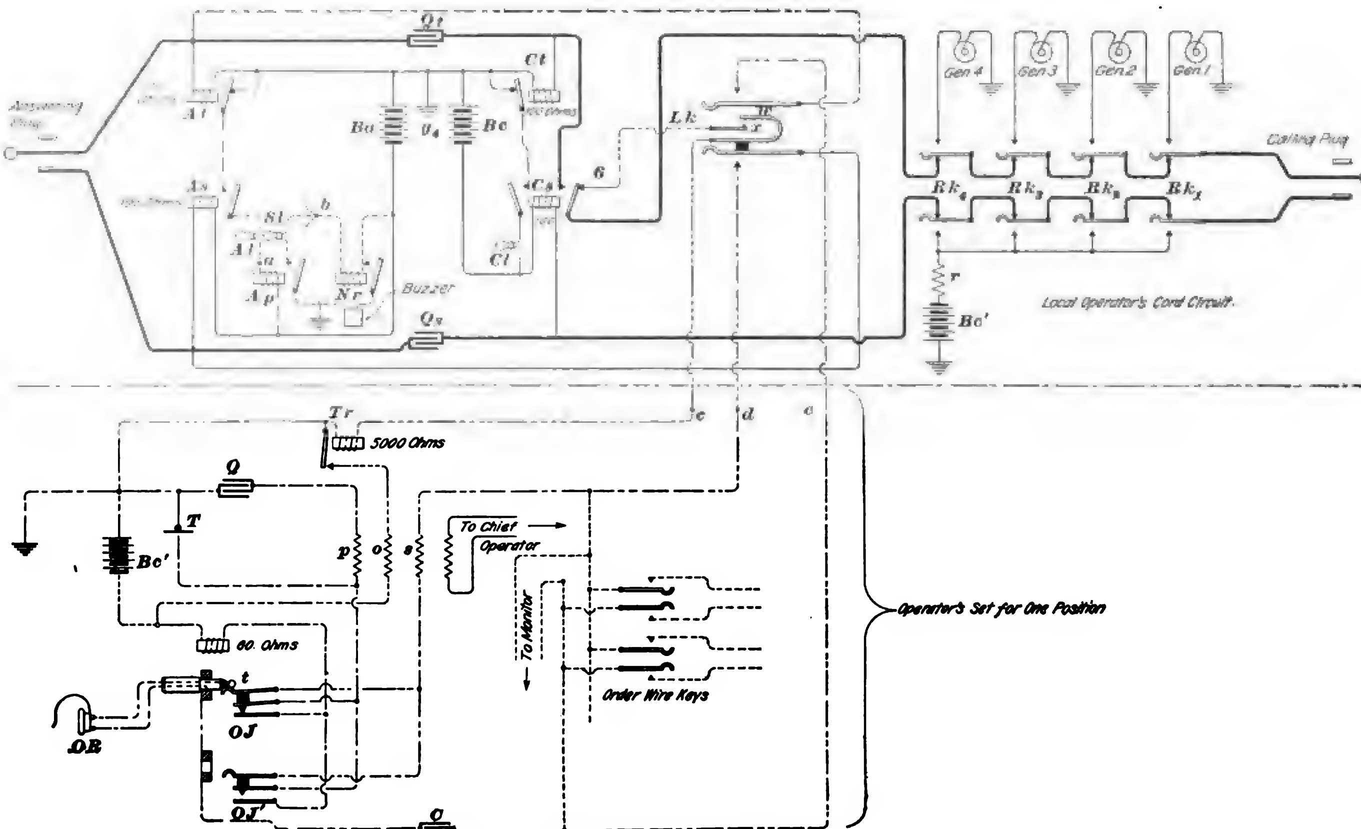

Answering Plug
Ct
Bo
Bc
Cs
Cl
Lk
6
Buzzer
Gen 4
Gen 3
Gen 2
Gen 1
Calling Plug
Bc'
r
Local Operator's Cord Circuit.
Tr
5000 Ohms
Q
T
p
o
s
To Chief Operator
To Monitor
60. Ohms
t
OJ
OJ'
OR
Order Wire Keys
Operator's Set for One Position

FIG. 11

simplify the connections. The way in which the supervisory-pilot lamp *Sl* is controlled by the pilot relay *Ap* and the buzzer, which is used as a disconnect night-alarm signal, by the relay *Nr*, will be clear enough from the connections shown. There is one supervisory-pilot lamp *Sl* and one supervisory pilot relay *Ap* for each operator's position and one night relay *Nr* and buzzer for all cord circuits on the entire board. The supervisory-lamp circuits for each position are collected together at some point, as *a*, and all the supervisory-pilot-lamp circuits are collected together at some point, as *b*.

In the lower left-hand portion of the figure is shown the subscriber-operator's set for one operator's position. This set branches at points *c*, *d*, *e* to the listening key in each cord circuit at this one operator's position. There are two exactly similar operators' jacks *OJ*, *OJ'*, connected in parallel, in either of which may be inserted the operator's receiver plug, and in the other the supervising operator's receiver plug. The insertion of a receiver plug in either jack closes the operator's transmitter circuit. The induction coil contains a fourth winding, which runs to the chief operator's desk, to enable the chief operator to listen on any operator's circuit without her knowledge or to talk with her. The monitor, also, has a circuit that is bridged across each operator's secondary circuit *s–t–OR–C*, thereby enabling her to converse with any operator. Any desired number of order-wire keys may be connected across each operator's secondary circuit, by means of which the subscriber operator may order a connection at a toll or trunk board or call the chief operator.

The ringing key is arranged for the Kellogg four-party-line system, which enables the operator to ring the bell of any one of four telephones that may be connected across that line. For this purpose, four ringing keys are connected to four generators of different frequencies. The battery *Bc'* holds the cut-off relay closed while ringing, as explained in connection with Fig. 10. The various parts of this circuit are lettered, as far as practicable, as in Fig. 10.

16. Sticking of Test Relays.—In some older Kellogg switchboards, the test relay *Tr* was connected directly to contact *6*, Fig. 11, on the relay *Cs* in each operator's cord circuit, there being no contacts *x*, *w* in each listening key. This causes a sticking of the test relay, due to current that leaked from the sleeve to the tip side of each cord circuit, through the test relay. Though this leakage may be very slight for any one cord circuit, as the test lead is common to all cords in one operator's position, the combined effect may be sufficient to operate the test relay, which is necessarily very sensitive. The trouble was remedied by placing contacts *x*, *w* in each listening key, thus allowing the test relay to be connected to but one cord circuit at a time. Where the older arrangement is used, the trouble may be partially remedied by using a good quality of switchboard cord, as the leakage occurs through the cord's insulation.

17. Line Circuit.—The method of running the line circuit in the exchange and the general form of relays is shown in Fig. 12 (*a*); at (*b*) is shown a simplified diagram of the line circuit. The lines are first brought to the lugs *w*, *x*, arranged vertically on the line side of the main distributing frame, from which the circuit is continued through jumper wires to the other side *y*, *z* of the main distributing frame where the lightning and sneak-current arresters are mounted. From there, they are carried, in cables, to the cut-off and line-relay rack. From there, three wires for each line are carried, in cables, to one side of the intermediate distributing frame from the same side of which the two line wires are carried, in cables, to the multiple jacks on the switchboard. Three branch wires are carried, by jumper wires, to the other side, and from there, in cables, to the answering jacks, line lamps, and other apparatus associated with that line.

When the cut-off relay is energized, the iron piece *a*, which rests on the edge of the iron piece *c*, is drawn up to the iron core, thereby raising the insulating piece *b* and with it the springs *i*, *e* out of contact with the springs *d*, *n*, and into

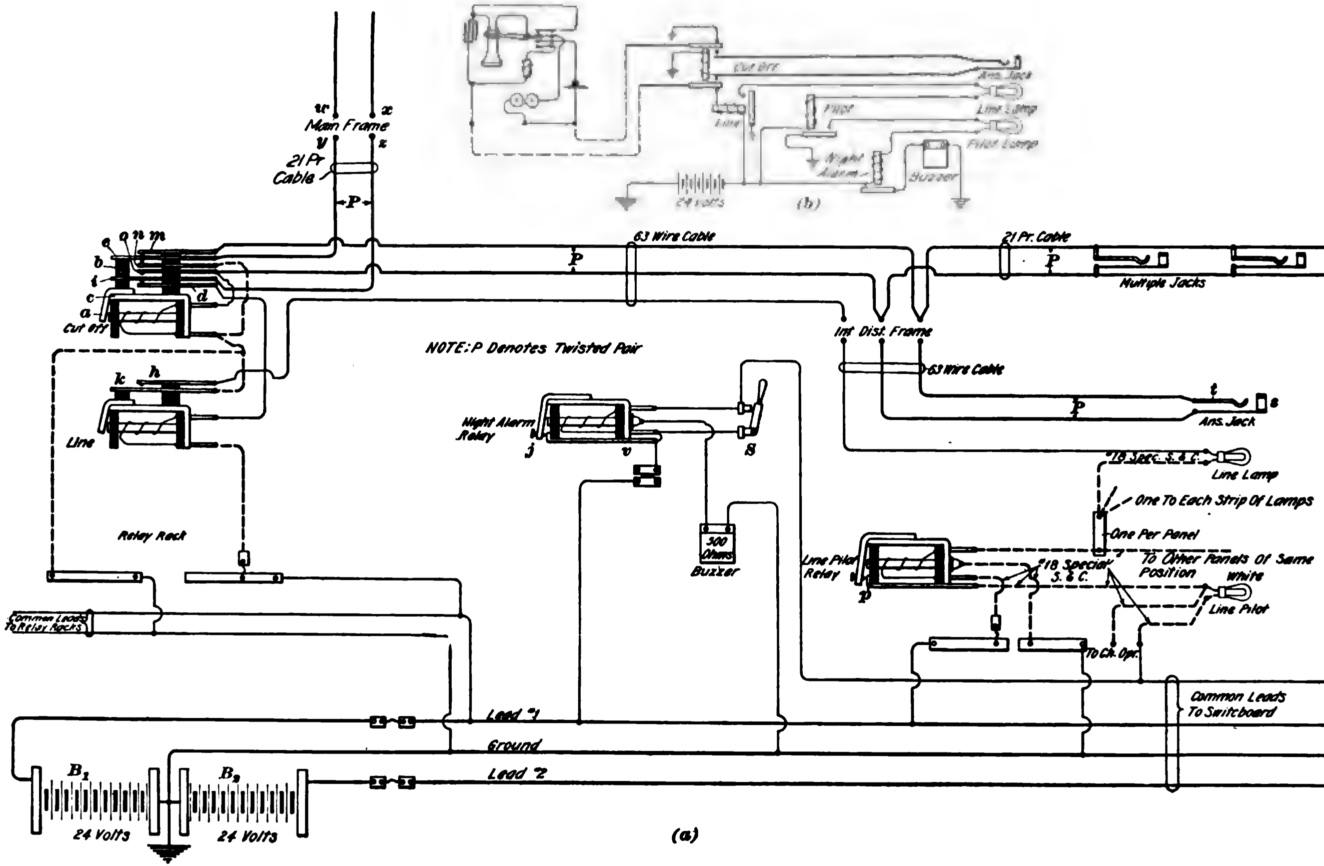

u
x
Main Frame
v
z
21 Pr Cable
P
e
o
n
m
b
i
c
d
a
Cut Off
k
h
Line
Relay Rack
Common Leads To Relay Racks
NOTE: P Denotes Twisted Pair
63 Wire Cable
21 Pr. Cable
Multiple Jacks
Int. Dist. Frame
63 Wire Cable
t
s
Ans. Jack
Night Alarm Relay
j
v
S
300 Ohms
Buzzer
#18 Spec. S. & C.
Line Lamp
One To Each Strip Of Lamps
One Per Panel
To Other Panels Of Same Position
Line Pilot Relay
p
#18 Special S. & C.
White
Line Pilot
To Ch. Opr.
Common Leads To Switchboard
Lead #1
Ground
Lead #2
B_1
B_2
24 Volts
24 Volts
(a)
Cut Off
Ans. Jack
Line Lamp
Pilot
Line
Pilot Lamp
Night Alarm
Buzzer
24 Volts
(b)

FIG. 12

contact with the springs *o*, *m*. All armatures are restored by gravity, and by the downward pressure of the contact springs *i*, *e*, to their normal positions, when the relays are deenergized. As there is only one night-alarm relay for all the line circuits entering the switchboard, a special large-coil relay of about 3-ohms resistance is commonly used. Current for the buzzer passes through *v*, *j*, armature, and core of the relay. When the line relay attracts its armature, *k* touches *h*.

18. Main and Intermediate Frames.—Though a subscriber may move from one part of the city to another, his new line can be readily connected, at the main distributing frame, to the same switchboard circuit as before; therefore, his line number does not have to be changed. By means of the jumper wires at the intermediate distributing frame, the jacks and line lamps of the busy telephones can be evenly distributed among all the operators without interfering with the multiple jacks or changing the line number of that subscriber. The number on the answering jack does not have to be the same as that of the line, but the number on the cap of the line lamp is changed to agree with the line number.

19. Cord Circuit.—Figs. 12 and 13 show the manner in which circuits are drawn by telephone manufacturing companies. Fig. 13 (*a*) shows the method of arranging the apparatus in a subscriber-operator's cord circuit, while Fig. 13 (*b*) is a simplified diagram of the same. In view (*b*), the wires *O* lead to the operator's listening set. As far as practicable, the same reference letters are used as in preceding figures.

20. Arrangement of Apparatus.—In exchanges built by the Kellogg Switchboard and Supply Company, the apparatus is generally arranged in about the following manner: The supervisory relays and all condensers are located in the rear of the board where there are suitable runways for the various connecting cables. The intermediate distributing frame has forty triple lug-connecting strips arranged vertically; to the answering-jack side are cabled directly all answering jacks and line lamps, while the multiple jacks are

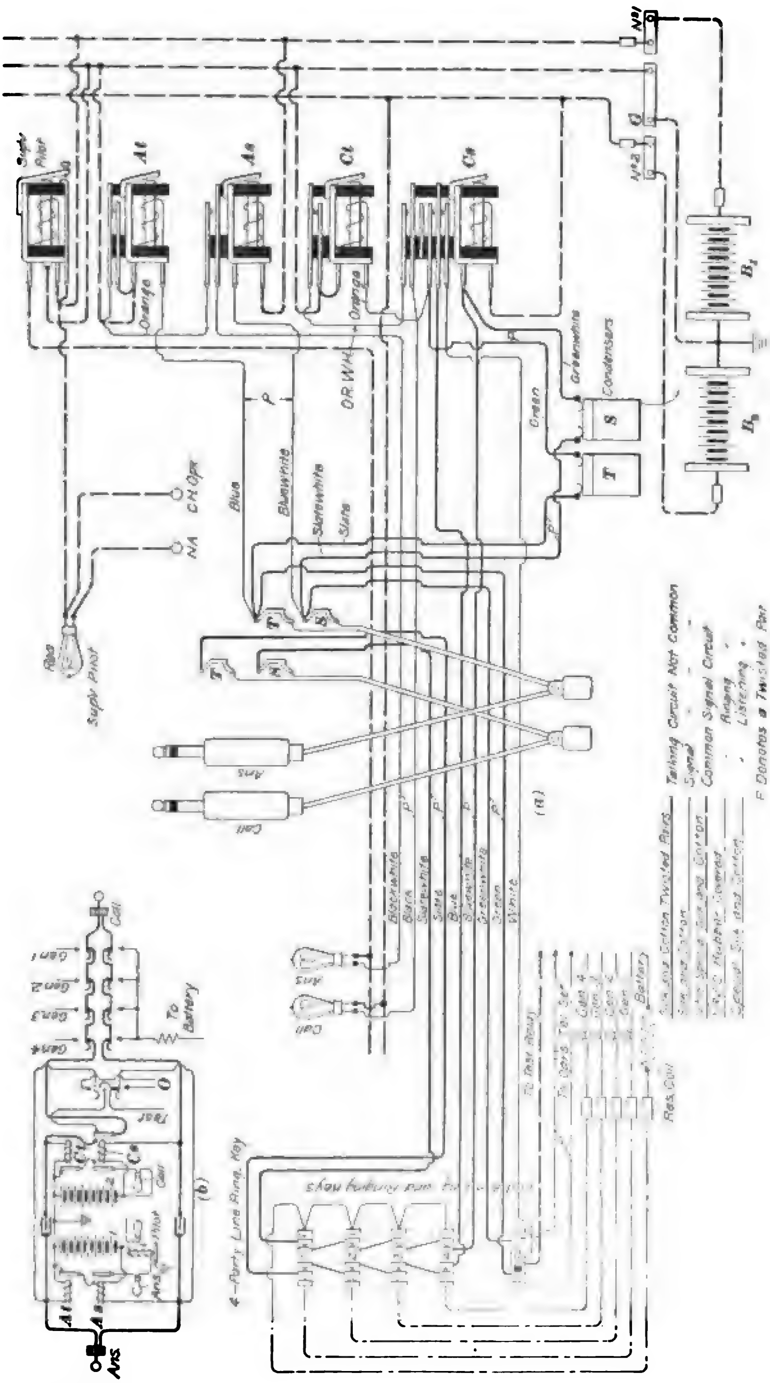

Supv Pilot
Red
HA
CH Opr
At
As
Ct
Cs
No 1
No 2
Orange
Blue
Blue-white
Slate-white
Slate
O.R.W.H.
Green
Green-white
Condensers
S
T
B_1
B_2
Ans
Call
(a)
(b)
Black-white
Black
Slate-white
Slate
Blue
Blue-white
Green-white
Green
White
Gen 1
Gen 2
Gen 3
Gen 4
To Battery
Test
4-Party Line Ring. Key
Res. Coil
Talking Circuit Not Common
Signal
Common Signal Circuit
Ringing
Listening
P Denotes a Twisted Pair

FIG. 18

cabled directly to the opposite side. This frame is situated in the terminal room. The relay rack may be placed behind it and is cabled directly to the multiple-jack side of the intermediate frame; the relays (a cut-off and a line relay being mounted in the same case) are arranged in groups called *bays*. The switchboard side of the main frame, which is connected by cable directly to the relay rack, contains the heat coils and lightning arresters, which are arranged in vertical strips, one pair of arresters being provided for each metallic line. On the opposite side of the main frame are located lug-connecting strips, also arranged vertically, to which the outside cables are attached. It is customary to provide just enough arresters for the lines in the switchboard, while the lug-connecting strips on the line side of the main frame are made about 25 per cent. greater, so as to provide connectors for cable pairs that are not in use. Thus, arresters are only necessary for lines that are actually working. Flame-proof jumper wire is used for cross-connecting the line-side lugs of this frame to the arresters on the switchboard side, thereby extending the lines to the relay rack, intermediate frame, and switchboard. The intermediate frame is cross-connected in the same manner as the main frame. The frames are made of angle iron entirely.

KELLOGG HARMONIC FOUR-PARTY-LINE SYSTEM

21. The **harmonic four-party-line system**, developed by W. W. Dean for the Kellogg Switchboard and Supply Company, is one of the few harmonic systems that has proved successful in practice. Its success is probably due to the care and skill with which all parts have been designed and also to the experimental tests made in order to improve the operation of the system as a whole. In this system, use has been made of the well-known fact that every reed has a natural, or free, rate of vibration, and that it can readily be made to vibrate vigorously by applying to it a succession of comparatively small impulses of the same frequency. A small amount of energy applied at a rate differing materially

from the free rate of vibration of the reed will not cause it to vibrate, at least not with sufficient amplitude to ring the bell. At each station, a specially constructed polarized bell is connected in series with a condenser across the line circuit, no ground connection being used. At the exchange, a ringing machine that will furnish ringing currents at four frequencies, any one of which may be sent over the line by means of a four-party ringing key, must be used. The only difference in the four bells is in the construction of the tapper, each being made to vibrate at a different rate.

22. The polarized harmonic ringer, made in 1905 by the Kellogg Company, is shown in Fig. 14. It resembles the

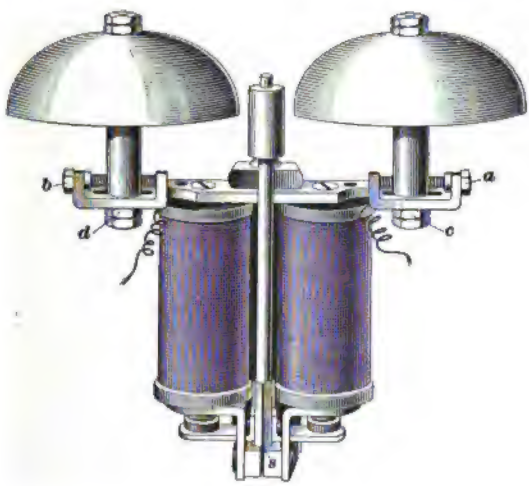


FIG. 14

ordinary ringer made by this Company, and supersedes the one-gong ringer previously made for this selective-ringing system. The position of the gongs may be accurately adjusted by screws *a b* and held securely in position by nuts *c*, *d*, the latter being provided with locknuts. The bell is self-contained, that is, all parts are mounted on one frame, and the permanent magnet is in metallic contact with the armature, which is suspended so as to form a reed that is acted on by electromagnetic impulses due to a ringing current

that passes through the two ringer coils, thereby making the armature vibrate with full amplitude, or swing, when the current impulses have the frequency corresponding to the natural period of vibration of the armature and rod. Four reeds having different free rates of vibration have been made by putting at their ends metal cylinders of different sizes, which serve also as tappers for striking the gongs. A constant stiff steel spring *s* seems to make the bells ring best; but, in order to avoid using too large a tapper for the lowest frequency bell, the spring *s* of this bell may be weakened slightly by punching a hole in it. All parts of the armature are permanently riveted together to avoid future adjustment and trouble. According to Mr. Dean, the actual free period of vibration of the armature is the resultant of the natural frequency of the reed as modified by the weight of the hammer and the action of the bell gongs when struck, giving a somewhat higher period than the natural period of the weighted reed alone.

23. Connection of Bells.—As shown in Fig. 15, a 1-microfarad condenser is in series with each of the four

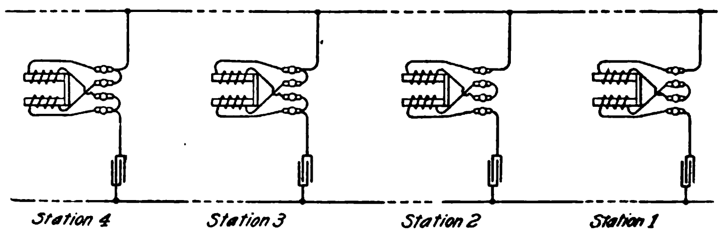


FIG. 15

bells, which are bridged across the line wires. The coils of the two low-frequency bells at stations *1* and *2* are connected in series, while those of the two high-frequency bells at stations *3* and *4* are in parallel; because, if the latter were in series, their impedance to the high-frequency current would be too high to allow enough current to pass through to properly ring the bell. The resistance of each coil is usually about 250 ohms. When current of a given frequency is applied to the line circuit, the armature naturally having the

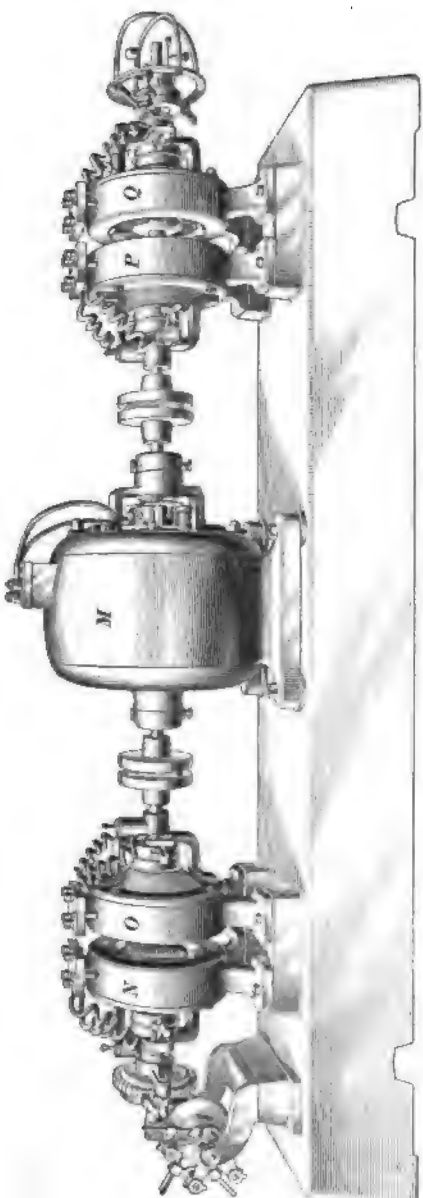


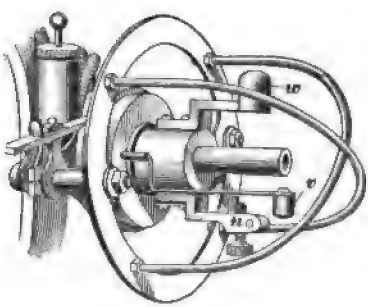
FIG. 16

same frequency vibrates with sufficient vigor to strike the gongs, while the reeds at the other three stations will not be appreciably affected. As low frequencies as practicable are used to avoid bad inductive troubles in the switchboard and on the lines. Experiments having shown that a satisfactory ring cannot be obtained under a frequency of 1,000 cycles, frequencies of 2,000, 4,000, 6,000, and 8,000 are generally used.

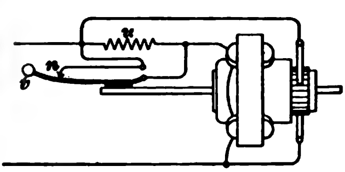
The current from the 4,000-cycle machine may be used for ringing ordinary polarized bells. The **ringing current** may be most easily obtained from generators having two, four, six, and eight poles, respectively, and driven at 1,000 revolutions per minute. The four generators *N*, *O*, *P*, *Q* shown in Fig. 16 are

mounted on a single base with a suitable motor *M* to which they are directly connected by the shaft; this set was made by the Holtzer-Cabot Electric Company. The ringing machines are built of different sizes to suit the exchange for which they are intended. In the exchange of the Frontier Telephone Company, of Buffalo, New York, about the first place where this system was installed, the ringing machine consists of four alternating-current ½-horsepower generators driven at a speed of 1,050 revolutions per minute by a 1-horsepower continuous-current motor to which they are directly connected. Each generator is provided with a different number of field poles, so that number *1* gives a current having a frequency of 1,050 cycles per minute; number *2*, a frequency of 2,100 cycles per minute; number *3*, 3,150 cycles per minute; and number *4*, 4,200 cycles per minute. Each generator is capable of supplying 1.5 amperes.

24. Speed Governor.—Commercial power circuits vary so much in voltage that it is necessary, in order to make a



(a)



(b)

FIG. 17

frequency system successful, to equip the motor with a speed governor that will maintain the speed and the frequency constant within allowable limits. The governor for this ringing set is shown mounted on the right-hand end of the shaft in Fig. 16, and more in detail in Fig. 17 (*a*); the left-hand end of the ringing set, Fig. 16, is equipped with a busy-back attachment. The electrical connections of the motor and governor are shown in Fig. 17 (*b*). A weight *v*

on the end of a spring is so mounted on the end of the shaft of the ringing set that when thrown outwards by centrifugal force it makes contact with *n*, thus short-circuiting a resistance *u* that is in series with the field coils of the motor. This resistance, when introduced into the field circuit, cuts down the amount of current flowing, thereby weakening the fields and increasing the speed of a shunt-wound direct-current motor. As it is desired to keep the speed of the ringing set constant at 1,000 revolutions per minute, the maximum variation of the power circuit being determined, the motor is designed to run too slow, without the governing resistance in circuit, on the highest voltage it can ever get, and to run too fast, with the governor resistance in circuit, on the lowest voltage it can ever get. The contact controlled by the governor is then adjusted so that the machine will run at 1,000 revolutions on its normal voltage. Then, as the speed of the machine tends to rise and fall with the variations in line potential, the resistance in the field circuit will be constantly cut in and out and the speed of the machine will remain very nearly constant. In a test made, this governor is claimed to have kept the speed of the set within less than 2 per cent. variation when the line voltage was varied more than 20 per cent. above and below normal. A stationary weight *w* is used to balance the governor.

25. Rotary Pole Changer.—For the use of small exchanges for which the expense of one of the regular

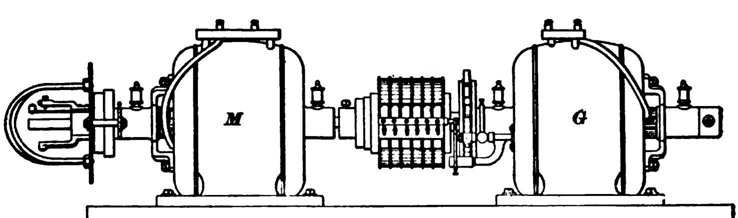


FIG. 18

ringing sets is prohibitive, the rotary **pole changer** shown in Fig. 18 has been designed. This pole changer consists of a motor *M* direct-connected to a direct-current generator *G*,

and equipped with the same governor used in the multicycle sets. The generator current is led by means of two slip rings to four commutators, which interrupt it at the desired frequencies. This pole changer may be also used as an auxiliary ringing machine in medium-sized exchanges. Mr. Dean does not recommend the rotary pole changer, as it is apt to cause bad inductive disturbances due to the sharp rise and fall produced in the strength of the interrupted current and also because it is cheaper, in the long run, to install the more complete ringing set. He recommends the application of a frequency governor to ringing outfits used in connection with party-line biased-bell systems.

26. Complete Ringing Circuit.—Fig. 19 shows the

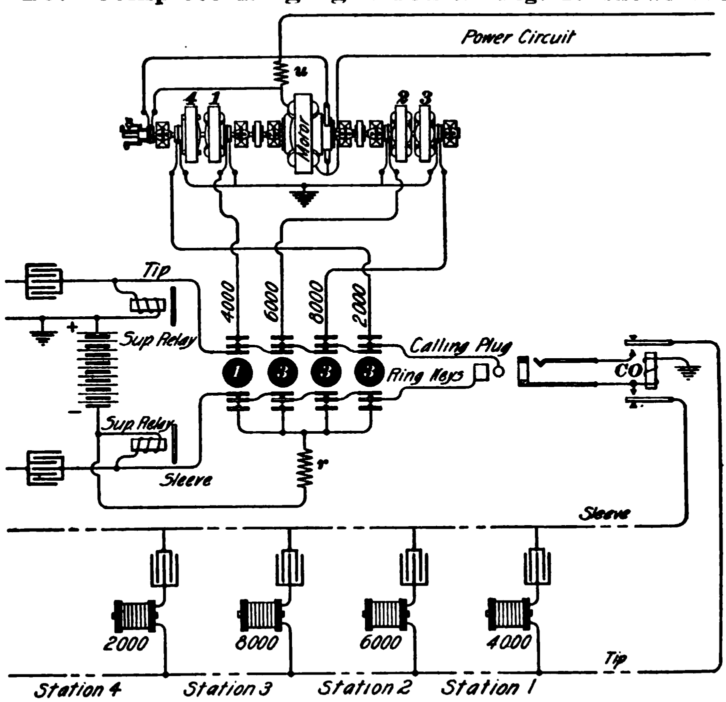


Fig. 19

Kellogg harmonic system adapted to a Kellogg central-energy switchboard, all parts unnecessary in this connection

being omitted. In connection with the calling side of one circuit is shown a four-party ringing key, to which are connected leads from the multicycle ringing set. When any ringing button is fully depressed, connection with the tip and sleeve strands of the cord circuit toward the answering end is broken and current flows from the battery through ground–cut-off relay *CO*–sleeve of plug and jack–resistance *r*, thus holding the cut-off relay closed and preserving the connection between the line and jack, so that the ringing current can flow through the tip side of the circuit–subscribers' bells–sleeve side–resistance *r*–battery–ground back to the generator. Depressing button *4*, for instance, connects the lowest frequency generator *4* in the following circuit: ground–generator *4*–key *4*–tip side of circuits–stations *1*, *2*, *3*, and *4*, which are in parallel–sleeve side of circuit–$\left\{\begin{matrix}\text{key } 4\text{–resistance } r\text{–battery} \\ \text{cut-off relay}\end{matrix}\right\}$–ground. Only the bell at station *4* rings because this current has a frequency corresponding to the natural rate of vibration of this bell only. The depression of any key connects the same numbered generator in a similar circuit across the line and rings only the one bell at the same numbered station.

When party lines form a large proportion of all the lines entering the exchange, the use of an individual indicating party-line key for each cord circuit is usually recommended; but when party lines form only a very small proportion of all the lines, a master party-line key may be used for each operator's position.

27. The **Kellogg listening-and-indicating, four-party, selective-ringing key** is shown in Fig. 20. *l* is the handle of the listening key, and *1*, *2*, *3*, and *4* are the ringing buttons. One key like this is connected in each cord circuit, and for this reason it is sometimes called an **individual party-line key.** In order to send ringing circuit to the line, it is necessary to depress a ringing button; when the button is released, the ringing circuit is opened, but the button does not revert to its normal position but remains

somewhat below the other buttons, as shown at *2*, so that in case a called subscriber does not answer promptly and must be rung a second time, the operator may know at a glance which party to ring without asking the calling subscriber. Pressing a second button automatically restores the one previously used. A small trip lever *e* is provided, by means of which any or all buttons may be restored. Individual keys in each cord circuit make the board much more rapid in

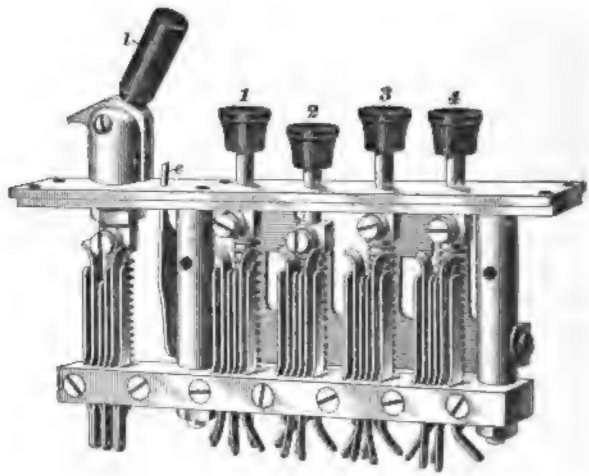


FIG. 20

operation than a board equipped with a master ringing key at each operator's position. The indicating feature of the key makes the service more satisfactory, as the subscriber is saved the annoyance of giving the number desired more than once.

The **Kellogg master ringing key** is the same, in general construction and appearance, as the individual party-line key, except that the listening key is not a part of the master key. One of these keys is installed at each operator's position and is so wired that it will switch the ringing current from any one of the four generators to the ringing strap wires common to all the regular ringing keys of the position. To signal a party-line subscriber, the operator first sets the master key and then rings with the regular ringing key of the

cord circuit in use. When a button is depressed, it is locked in that position; the depression of another button releases the one previously depressed and also opens the circuit between the ringing strap and the ringing generator previously in use. A small trip lever is provided by means of which any or all buttons may be restored.

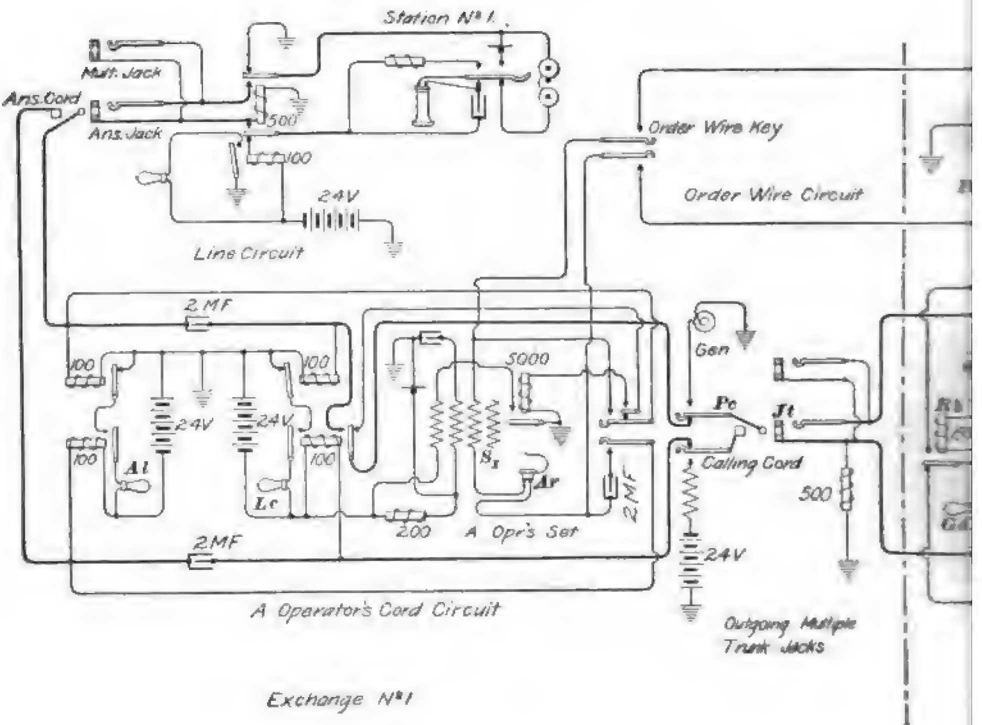
KELLOGG TRUNKING CIRCUITS BETWEEN EXCHANGES

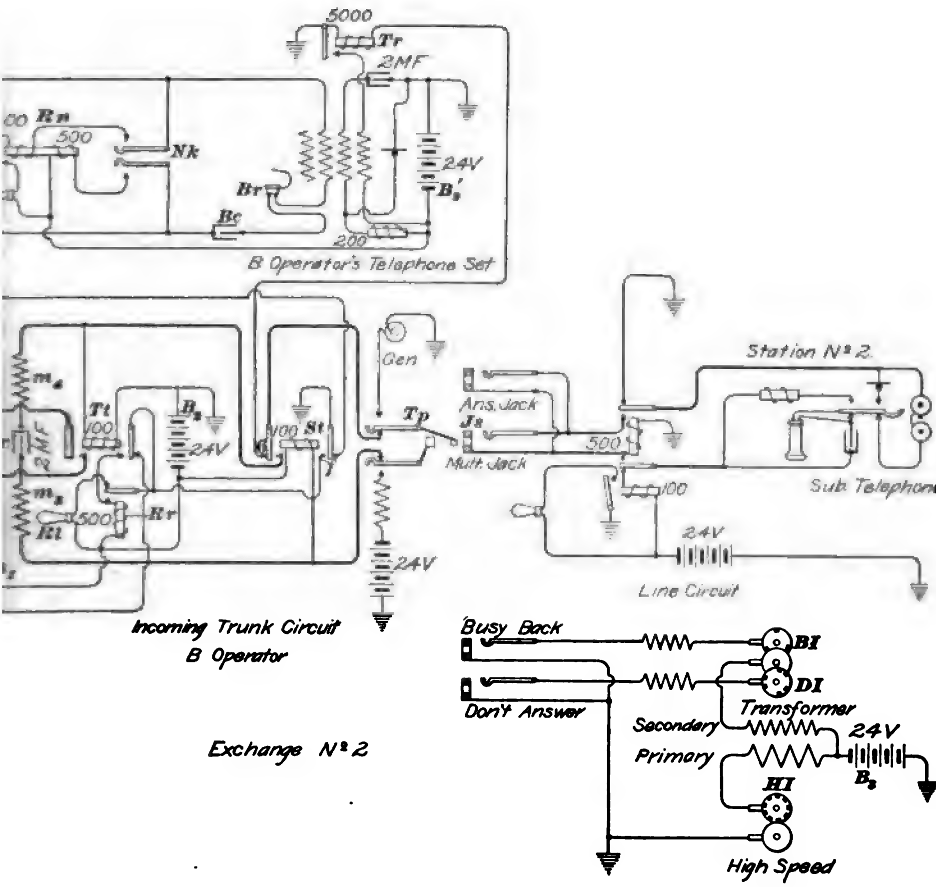
28. Outline of Operation.—The **Kellogg trunking circuit** used between central-energy exchanges for the rapid interconnection of subscriber's lines, works on the so-called standard system of trunk signaling. The *A*, or subscriber, operator, on receiving a call for a party located in another exchange, talks over an order-wire directly into the head-receiver of the *B*, or incoming-trunk, operator at the desired exchange. The *B* operator designates an idle trunk, into the end of which the *A* operator inserts the calling plug of the pair of cords used in answering the call, thereupon ending her part of the connection. The *B* operator tests the multiple jack of the desired subscriber's line in the usual manner, and if not busy inserts the trunk plug designated and rings the subscriber. When the subscriber responds, the calling supervisory lamp at the *A* operator's position is extinguished, as well as a ringing lamp associated with the trunk plug at the *B* operator's position, the latter lamp remaining inoperative until after the whole connection is restored to normal. When both subscribers are through talking and hang up their receivers, the two supervisory lamps in the *A* operator's cord circuit light but no signals are shown at the *B* position, thus bringing the supervision back to the originating, or *A*, operator. The *B* operator receives her disconnect only after the *A* operator has removed the calling plug from the trunk jack, or, as it is commonly stated, has pulled down her part of the connection. In this manner, the entire responsibility of the disconnecting is vested in one operator, thereby avoiding many mistakes.

29. Trunk Circuits.—The operation of the Kellogg trunk circuit, in detail, is rather complex, but, by the aid of several figures showing the conditions at the various stages of the connection, the operation can be clearly explained. Fig. 21 shows all the circuits necessary for a complete connection between two subscribers' telephones that terminate in different city exchanges, while Figs. 22 to 26, inclusive, show the condition of the trunk circuit during the various stages of the connection. In Fig. 21, all the circuits shown at the left of the vertical broken line are in exchange number *1* and consist of a standard Kellogg subscriber's line circuit and an *A* operator's cord circuit, also the multiple jacks of the outgoing-trunk line to exchange number *2*. At the right of the broken line will be found the incoming-trunk circuit and a *B* operator's telephone circuit, as well as a standard Kellogg line circuit. The busy-back and don't-answer circuit, for use in connection with the trunk circuit, is also shown in exchange number *2*.

OPERATION

30. If the subscriber at station number *1*, whose line terminates in exchange number *1*, wishes to talk with subscriber number *2*, of exchange number *2*, he will make the call in the regular way. The *A* operator responds by inserting the answering plug of a regular cord circuit into the answering jack and throwing the listening key in the usual manner. Finding that the party desired is in another exchange, the *A* operator will immediately press an order-wire key, which will connect her talking set directly with the *B* operator's head-telephone Br, and repeats the call. At night or at other times when the *B* operator leaves her position, the key Nk is thrown so as to bridge the battery B_{2}' across the order-wire circuit through the two 500-ohm windings of the relay Rn. Then, on pressing the order-wire key, the circuit of the battery B_{2}' is completed through the right-hand winding of relay Rn–lower contact of key Nk–lower half of order-wire circuit–lower contact


Station Nº 1.
Mult. Jack
Ans. Cord
Ans. Jack
500
100
24V
Line Circuit
Order Wire Key
Order Wire Circuit
2 MF
100
100
100
100
5000
Gen
Pc
Jt
24V
24V
Al
Lc
S_1
Ar
Calling Cord
500
200
A Opr's Set
2 MF
2 MF
24V
A Operator's Cord Circuit
Outgoing Multiple Trunk Jacks
Exchange Nº 1



5000
Tr
2MF
Rn
500
Nk
24V
B_2'
Br
Bc
200
B Operator's Telephone Set
Gen
Station No 2.
m_4
Tt
100
2MF
B_2
24V
100 St
Tp
Ans. Jack
J_2
500
Mult. Jack
Sub. Telephone
m_3
500
Rr
Rl
100
24V
24V
Line Circuit
Incoming Trunk Circuit
B Operator
Busy Back
BI
Don't Answer
DI
Transformer
Secondary
24V
Primary
B_2
HI
High Speed
Exchange No 2

on order-wire key–operator's head-telephone Ar–secondary of operator's induction coil S_1–upper side of order-wire key, order-wire circuit, and key Nk–left-hand winding of relay Rn–ground side of battery B_2'. Current flowing through the two windings of relay Rn causes it to attract its armature and light the pilot lamp Pn. A night-bell circuit is usually arranged to be connected in series with this pilot-lamp circuit so that an audible signal can be had, if desired, and thereby immediately call the attention of the attending operator, who might be engaged in work at other positions.

31. The B operator's telephone set is the same as that of the A operator, but is not provided with a listening key and has only a test connection with the incoming-trunk circuits. The only time the B operator has an opportunity to talk is while the order-wire key at exchange number *1* is pressed. Then she can repeat the order given by the A operator and designate an idle trunk. As soon as the A operator receives this information, she releases her order-wire key and inserts the calling plug Pc of the cord circuit into the multiple jack Jt of the specified trunk. These trunk jacks are multipled once every section of the A switchboard and are located in a space provided for them between the regular answering and multiple jacks. Thus, each A operator can readily reach a multiple jack of any outgoing trunk.

Assuming that the A operator plugs into the designated outgoing-trunk jack Jt before the B operator inserts the trunk plug Tp into the multiple jack Js of the subscriber's line circuit, the condition shown in Fig. 22 will exist. A path for current from battery B_1 will be established through the sleeve relay Sc–sleeve of plug Pc and trunk jack Jt–500-ohm retardation coil Rc–ground terminal of battery. This will operate relay Sc and cause the calling lamp Lc to light, as indicated in this figure. Another path for the current is from battery B_1 through the sleeve relay Sc–sleeve of plug Pc and trunk jack Jt–winding m_1 of repeating coil–15,000-ohm relay Rb–winding m_2 of repeating coil–tip of trunk jack Jt and plug Pc–tip relay Tc–ground terminal of

battery. Relay *Tc* will not be affected because of the high resistance of relay *Rb*, but the latter will be energized and close a circuit from battery B_2 through the guard and disconnect lamp *Gd*–contact *a* of relay *Rb*–contact *7* of relay *St*–*g* to grounded terminal of battery B_2; this will light *Gd* and serve as a notification to the *B* operator that the proper trunk jack has been used by the *A* operator.

32. At the same time that the *A* operator plugs into the designated trunk jack *Jt*, the *B* operator is engaged in testing the multiple jack *Js* of the desired subscriber's line (see Fig. 21). This test is made in the same manner as with a local, or *A*, operator's cord circuit. The test circuit from the tip of the trunk plug *Tp* goes through the left-hand back-contact *6* of relay *St*, thence through the test relay *Tr* to ground. When the relay *St* is energized, the test connection to the *B* operator's telephone set is automatically removed and the talking circuit established through the tip side of the trunk circuit. This relay *St* is operated when the *B* operator plugs into the multiple jack of the designated line, as shown in Fig. 23, the circuit being from battery B_2 through relay *St*–sleeve of plug *Tp*–sleeve of jack *Js*–line cut-off relay–ground to battery. The cut-off relay of line *2* is thus operated, establishing the line circuit from the multiple jack to the subscriber's station *2*. The operating of relay *St* opens at *7* the grounded circuit containing the lamp *Gd*, thereby extinguishing it and at the same time connecting the same ground plate *g* to contact *f*, and thus lighting the ringing lamp *Rl* through the back contact *8* of relay *Rr*, the current being furnished by B_2.

33. The *B* operator rings the subscriber in the regular way, knowing by the extinguishing of the lamp *Rl* when the party responds. The supervisory lamp *Lc* in the *A* operator's cord circuit also goes out at the same time, notifying the *A* operator that the connection is completed and that subscribers *1* and *2* are conversing. The condition of the trunk circuit at this stage is shown in Fig. 24. The removing of the receiver at station number *2* establishes a circuit

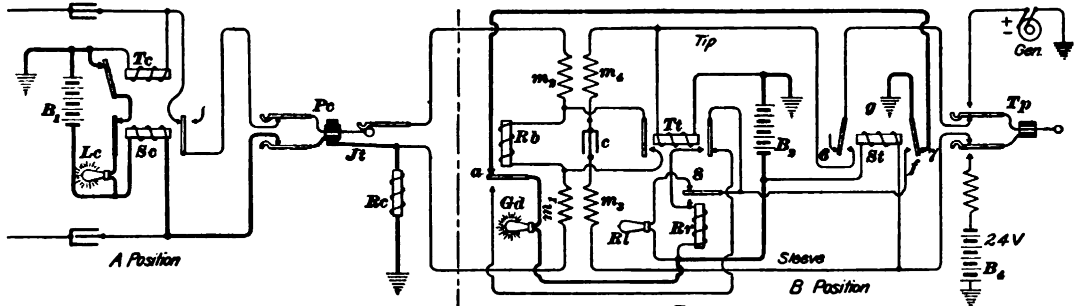

Tc
B1
Lc
Sc
A Position
Pc
Jt
Rc
Tip
m2
m4
Rb
c
Tt
B2
g
St
a
Gd
m1
m3
8
Rl
Rr
Sleeve
B Position
6
f
7
Gen.
Tp
24 V
B4

FIG. 22

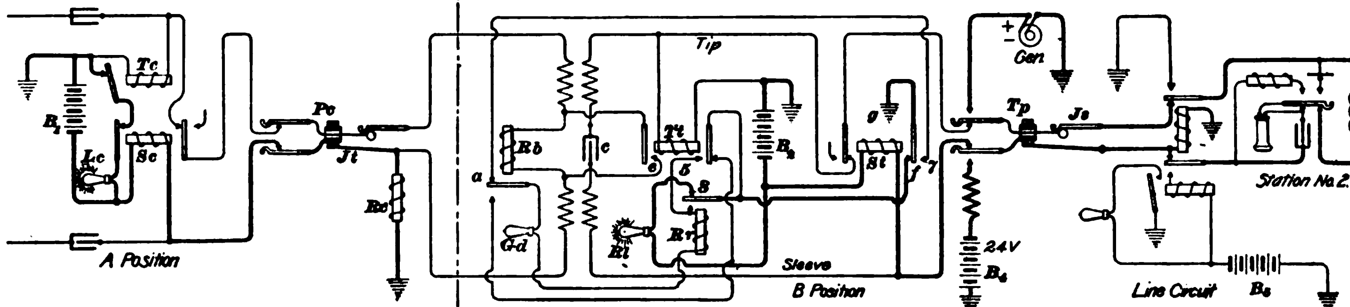
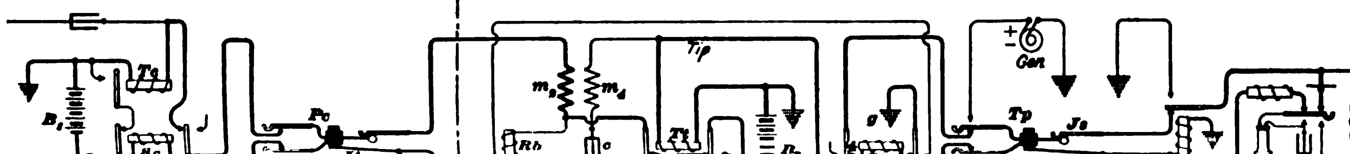

Tc
B1
Lc
Sc
A Position
Pc
Jt
Rc
Tip
Rb
c
Tt
B2
g
St
a
Gd
6
5
8
Rl
Rr
Sleeve
B Position
f
7
Gen
Tp
Js
24 V
B4
Station No. 2.
Line Circuit
B5

FIG. 23


Tc
B1
Sc
Pc
Jt
Tip
m2
m4
Rb
c
Tt
g
Gen
Tp
Js

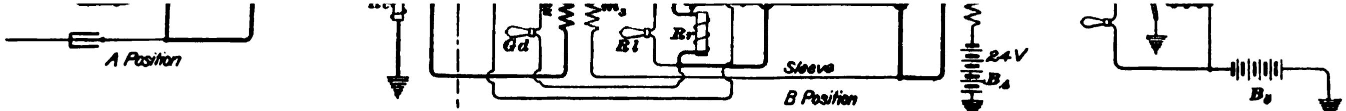


FIG. 24

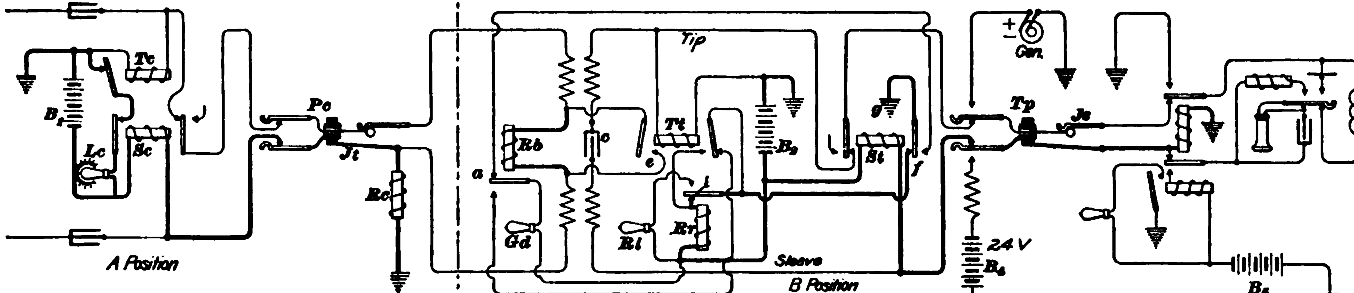


FIG. 25

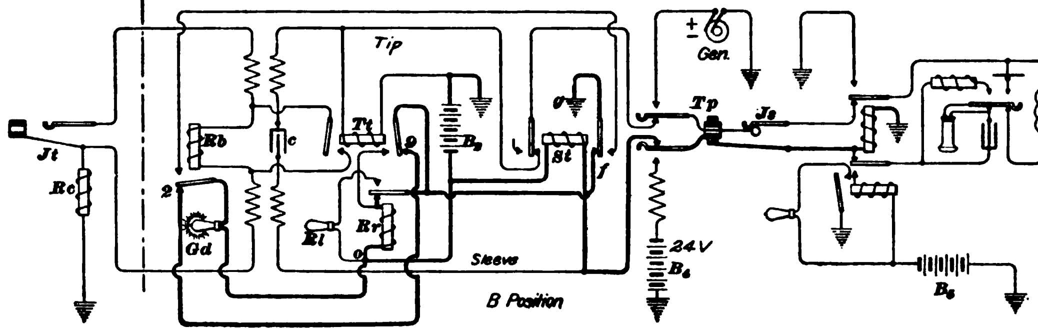


FIG. 26

from the battery B_2 through–tip relay Tt–closed contact *4* of relay St–tip of trunk plug Tp–tip of jack Js and line–subscriber's telephone–sleeve of line, jack and trunk plug–winding of relay St to battery B_2. When the relay Tt is operated, its left-hand contact e short-circuits the high-wound relay Rb, thus reducing the resistance of the trunk circuit, so that the tip relay Tc will operate and extinguish the supervisory lamp Lc. The operation of the relay Tt, also, by closing contact *5*, establishes a circuit from battery B_2 through ground–g–f–*5*–relay Rr to B_2, thus operating the relay Rr, breaking the circuit of the ringing lamp Rl, and extinguishing the same. As there is no further use for this lamp until the trunk is used on another connection, its controlling relay Rr closes contact i when it operates which renders it independent of the relay Tt and thereby locks it in its operated position. This circuit can be traced from battery B_2 through ground–g–f–closed contact i–winding of relay Rr to B_2, for the relay St is held in its operated position by reason of the trunk plug Tp being inserted in the multiple jack Js of line *2*.

During conversation, station *2* is fed with current for talking from battery B_2, the two relays Tt, St, having resistances of 100 ohms each, serving the same purpose as the tip and sleeve relays in the *A* operator's cord circuit. The repeating coil m_1, m_2, m_3, m_4 separates the batteries B_1, B_2 of the two exchanges, preserving the signaling conditions and preventing disturbances that would otherwise be caused, due to the presence of grounds on both of these batteries. B_2, B_4, and B_6 are the same batteries.

34. When the parties are through talking and hang up their receivers, both supervisory lamps light in the *A* operator's cord circuit, but no signal is displayed at the *B* operator's position. The hanging up of the receiver at station *2* puts the trunk circuit in the condition shown in Fig. 25. Relay Tt becomes deenergized, thereby opening contact e, which removes the short circuit from relay Rb and consequently increases the resistance of this half of the trunk line by the

resistance of this 15,000-ohm relay *R b*. This half of the trunk is then of sufficient resistance to cause the tip-cord relay *T c* to release its armature; this lights the supervisory lamp *L c*. The other supervisory lamp *A l*, Fig. 21, of this cord circuit is lit by the hanging up of the receiver at station *1*.

Now that both disconnect signals are displayed, the *A* operator pulls down the connection, thus deenergizing the relay *R b* by removal of the battery B_1, as shown in Fig. 26. The falling back of the armature of this relay lights the disconnect lamp *G d*, the current being supplied from battery B_2 through the ground-*g*-*f*-*9*-*2*-*G d*-*o*-to B_2. Current also continues to flow through the relay *R r*, which is now in parallel with the lamp *G d*. The removal of the trunk plug *T p* restores everything to normal, as shown in Fig. 21.

35. Busy-Back and Don't-Answer Devices.—As the *B* operator has no means for conversing with the *A* operator or with the waiting subscriber, she is provided with a special tone-test circuit, which terminates in **busy-back** and **don't-answer jacks,** as shown in Fig. 21. The busy-back jack has its tip connected through a suitable resistance to a revolving contact wheel *B I* that opens the circuit of the battery B_3 (the same battery as B_2) three times each revolution, while the don't-answer jack is connected to a similar contact wheel *D I* that opens the same battery circuit at irregular intervals and is easily distinguishable from the former. An extra contact wheel *H I* provided with a great number of fine segments opens the primary circuit of the transformer at a sufficient rate to give a musical tone due to the current impulses of musical frequency that are superimposed by induction from the primary current on the battery current flowing in the secondary winding, which latter is electrically connected to the interrupters *B I* and *D I*.

If a line tests "busy," or the subscriber does not respond when rung, the *B* operator inserts the trunk plug *T p* in the busy-back or don't-answer jack, as the case requires, leaving the circuit in this condition until the disconnect lamp *G d*

signals her to pull down the connection. The opening and closing of the interrupter contacts *B I* or *D I* cause the trunk and *A* operator's cord circuit to alternately assume the conditions shown in Figs. 24 and 25, thus flashing the supervisory lamp *L c*. For, when current flows from the battery B_3, Fig. 21, through either of the interrupting devices *B I*, *D I* and the tip side of the circuit, the relay *T t* is energized, the relay *R b* is short-circuited, the relay *T c* energized, and the lamp *L c* is not lighted, this condition being shown in Fig. 24. When either interrupting device cuts off the battery current, *T t* releases its armature, *R b* is no longer short-circuited, *T c* does not receive enough current to hold its armature, and the lamp *L c* is lighted, this condition being shown in Fig. 25. The *A* operator, knowing the speed of the lamp flashing, tells the calling subscriber the reason for not being able to make the connection and then pulls down the cords; this lights the trunk disconnect lamp *G d*, as previously described and shown in Fig. 26, thus signaling the *B* operator to remove the trunk plug from the busy-back or don't-answer jack.

The placing of the trunk plug in the busy-back or don't-answer jack will also cause the interrupted tone to be connected through the tip of such jack and trunk plug–winding m_4 of repeating coil–condenser *c*–winding m_3 of repeating coil–sleeve of plug *T p* and sleeve of busy-back or don't-answer jack to ground side of battery, thereby affecting, by induction in m_1, m_2, the receiver of the calling subscriber at station *1*. The subscriber, hearing the tone, will, if he understands its significance, hang up the receiver and thus light the corresponding disconnect lamp, so that the *A* operator will have the double disconnect signal and can thus pull down the cord circuit without throwing the listening key and verbally notifying the waiting subscriber of the condition of the connection.

KELLOGG PRIVATE-BRANCH-EXCHANGE SYSTEMS

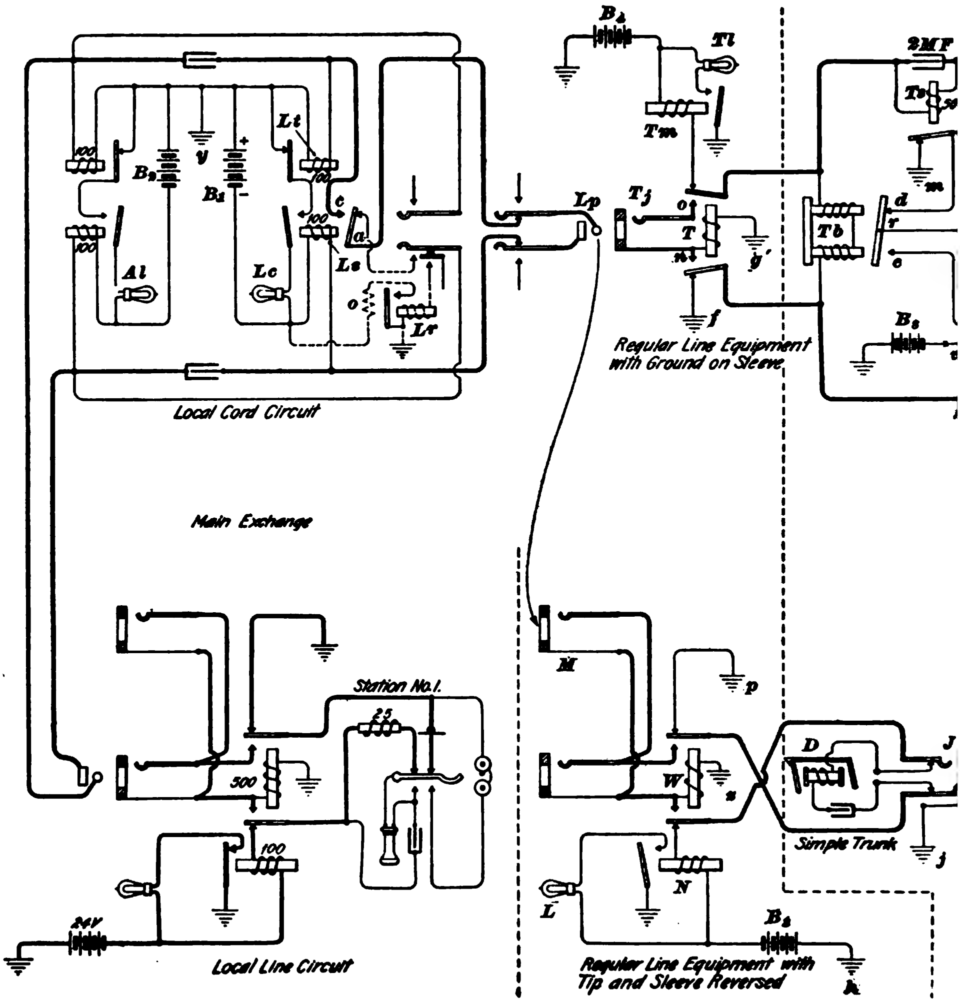
36. As the name **private-branch exchange** implies, it is a complete and private exchange equipment arranged to serve a small locality or building; and being connected to the city exchange by trunk lines it becomes known as a *branch*.

The Kellogg Company, like other large manufacturers of telephone apparatus, has been called on to furnish many types of **private-branch-exchange systems** varying mainly in the design of the trunking equipment.

The line and cord circuits are very simple, being of the three-conductor type. The line circuit, shown at the extreme right of Fig. 27, employs a cut-off jack *Pj*, having inner platinum-pointed contacts for cutting off the signaling apparatus when the plug is inserted. These contacts take the place of the usual cut-off relay, which, in the case of ordinary private-branch exchanges, would take too much room, as all the apparatus, excepting the batteries and power-plant equipment, is housed in the switchboard cabinet. Moreover, such switchboards are not usually large enough to require multiple jacks; hence, cut-off relays are unnecessary.

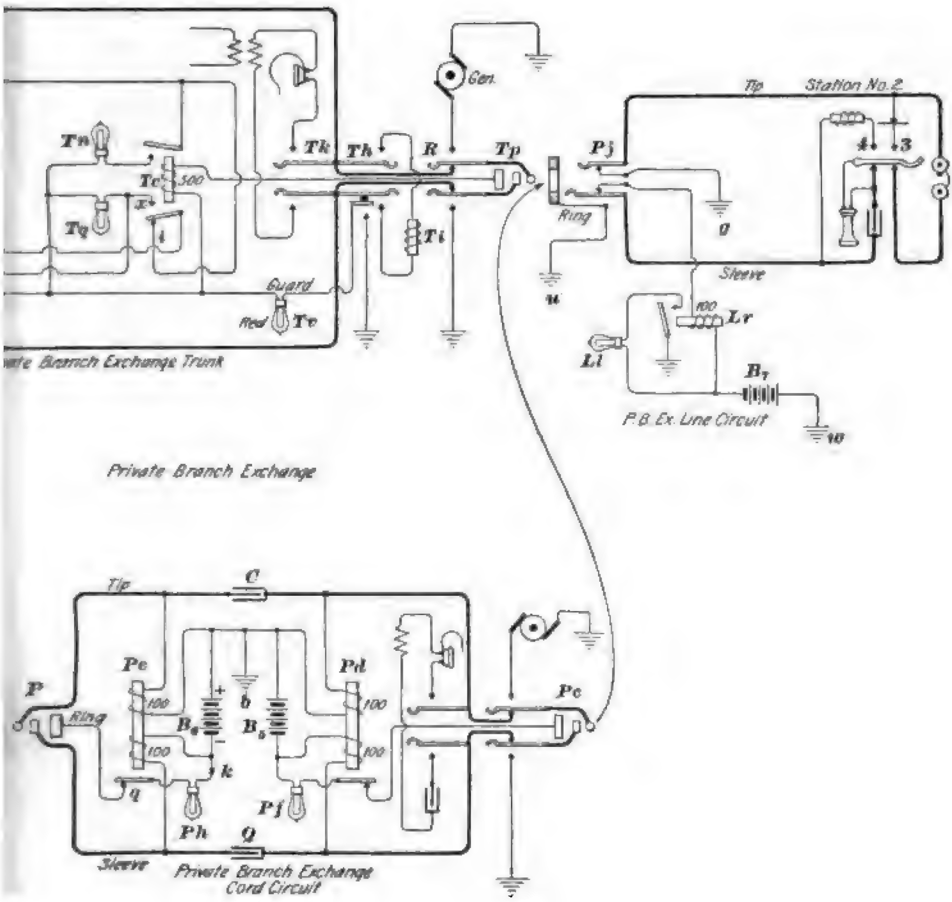
The private-branch-exchange cord circuit is provided with two tandem-wound relays *Pe*, *Pd* that operate the supervisory signals and also serve as retardation coils through which the branch-exchange batteries B_6, B_6 feed the cord circuit. Two condensers *C*, *Q*, one in each of the connecting strands of the cord circuit, separate the answering from the calling part of the circuit and thereby preserve the signaling as well as the talking properties. The operator's transmitter circuit, although not shown in this figure, is connected as shown in Fig. 10 (*b*). One supervisory-pilot relay controlling a pilot lamp may be connected in the return circuit *k* of all supervisory lamps *Ph* at each operator's position. Self-restoring target signals may be substituted for the relays *Lr*, *Pe*, *Pd*, if lamp signals are not desired.

37. Branch Subscriber Calling Branch Exchange. When the receiver at station *2*, Fig. 27, is taken down,



KELLOGG PRIVATE-BRANCH E

F



IANGE AND TRUNK CIRCUITS

contacts *3*, *4* are closed and current from B_7 flows through *w*–*g*–tip conductor–transmitter–contacts *3*, *4*–impedance coil–sleeve conductor–100-ohm line relay *L r*–B_7, thus pulling up the armature of the line relay *L r* and lighting the line lamp *L l*, which is associated with the jack *Pj*. Inserting the answering plug *P* into the line jack *Pj* cuts off the line signaling circuit, extinguishes the line lamp *L l* and closes the circuit of battery B_8 through the supervisory lamp *Ph*–back contact *q* of relay *Pe*–ring of plug *P* and jack *Pj*–*u*–*b*. The lamp is thus lighted when no current is flowing through the windings of relay *Pe*, which is the case when the receiver is hung up at station *2*. However, when the line is in use, the battery current for talking is fed through the windings of relay *Pe*, the same as in the case of the two relays in each half of the Kellogg multiple-switchboard cord circuit, and its armature is attracted, thus extinguishing the lamp *Ph*. The feeding of battery and the operation of the supervisory lamp in the calling half of this cord circuit is the same as for the answering half. These simplified circuits, therefore, operate with the same system of lamp signals and talk under the same conditions as those of the more complicated Kellogg multiple board.

38. Trunk Circuits.—The trunk lines connecting the private-branch exchange with the main exchange are designed to work in both directions; i. e., an operator at either exchange can call the operator at the other exchange, thus getting double service. In order to prevent confusion at the main board, the trunk line terminates in a regular multiple line circuit so that the local operators will not be required to do special work, the private-branch-exchange calls being handled the same as regular calls.

Two trunk circuits are shown in Fig. 27; the private-branch-exchange trunk represents the more complete system of signaling, while the simple trunk is a simplified circuit that is used where the minimum amount of equipment is desirable. The former terminates at the private-branch exchange in a cord and plug *Tp* and thus makes the connections with the

branch-exchange lines direct, while the latter terminates in a jack J, requiring the use of a branch-exchange cord circuit to complete the connection. The more complete private-branch-exchange cord-and-plug trunk, or *plug-ended trunk*, as it is sometimes called, is designed to allow the feeding of talking battery from the main exchange direct to the branch subscriber's telephone, thereby carrying the signaling back to the local operator, who, in a way, has control of the connection.

The main switchboard end of the trunk terminates in a regular line circuit, with the exception that the battery B_4 and the line relay Tm are connected to the tip and the ground f to the sleeve, thus reversing the usual polarity of the regular line conductors. At the private-branch exchange, a 15,000-ohm polarized relay Tb is permanently bridged across the circuit, being connected so that the current from the battery, which is normally connected across the line, keeps its armature in the position shown. The high resistance of this relay prevents the operation of the line relays at the main board, which at best are adjusted to operate through 2,000 ohms and fail to operate through 10,000 ohms. Current is necessarily flowing through this bridged relay at all times, but as its resistance is so high the waste of current is negligible.

A 50-ohm series-relay Ts is included in the tip of this trunk at the branch-exchange end so as not to impair the feeding of current from the main-exchange battery to the branch-exchange subscriber's station. A 2-microfarad condenser is bridged across the terminals of this relay to provide a path for voice currents, which would otherwise be greatly reduced by the retardation of the winding. This relay is controlled by the branch-exchange subscriber, as subsequently described. A 500-ohm relay Tc is connected to the third, or ring, strand of the trunk cord and is operated by inserting a plug in a branch-exchange line jack.

OPERATION OF COMPLETE TRUNK CIRCUITS

39. If a call is made by a subscriber at station *1* for a party at station *2* of the private-branch exchange, the local operator at the main board treats the connection the same as for all other local connections and if the trunk line tests "not busy," inserts the plug Lp of the calling cord into the multiple jack Tj. In case the multiple of the trunk is busy, the local operator tests for a non-busy jack of the other trunks to this same branch exchange, of which there are usually several. These extra trunks are made known to the local operator by special markings, made on the face of the jack-strips; in many cases these trunks are grouped with a designation line painted under or around the several jacks.

40. Main Exchange Calling Branch Exchange. The inserting of the calling plug Lp in jack Tj establishes a circuit from battery B_1 through y–ground–g'–cut-off relay T–sleeve of jack Tj and plug Lp–sleeve relay Ls–battery B_1, thus closing both relays T and Ls, and a circuit from B_1 through the tip relay Lt–c–a–tip of plug Lp and jack Tj–contact o–relay Tb–contact n–sleeve of jack Tj and plug Lp–sleeve relay Ls–battery. The current through the high-wound relay Tb is now of opposite polarity to that normally connected to line through the back contacts of the cut-off relay T, so that its armature opens the contact at d and establishes a contact at e. The closing of contact e provides a circuit for battery B_1 through the calling and disconnect lamp Tq–contact e–r–armature and back contact i of relay Tc–back contact of relay Ts–ground m–B_1. The calling lamp Tq, which is associated with and located near the trunk plug Tp in the key shelf, is thereby lighted. The current through the tip relay Lt of the cord circuit at main board is not strong enough, due to the high resistance of relay Tb, to operate the relay Lt; but the sleeve relay Ls is operated, as in any local connection, by current through the winding of the cut-off relay T and sleeve strand of the cord. Thus the calling supervisory lamp Lc is lighted and remains in

this condition until the private-branch operator responds by throwing her listening key Tk, which connects her head-telephone and the secondary of her induction coil across the circuit. Current from battery B_1 now has a sufficiently low resistance path through the operator's listening circuit to operate the tip cord relay Lt and thereby extinguish the calling supervisory lamp Lc, the circuit being as follows: Battery B_1–tip relay Lt–c–a–tip of trunk line–relay Ts–tip side of listening key Tk–operator's head-telephone–secondary of operator's induction coil–sleeve side of listening key Tk –sleeve of trunk line–sleeve relay Ls–battery B_1. The armature of relay Ts will be attracted, thereby opening the circuit of battery B_8 through the trunk calling lamp Tq and extinguishing the same. The current in this lamp circuit is thus cut off for the reason that the night alarm, not shown in this figure, would otherwise be operating during the entire time the branch operator was conversing with the distant subscriber and until the plug Tp was inserted in jack Pj, thereby operating relay Tc.

41. Call Completed.—The private-branch operator responds to the call by inserting the trunk plug Tp into the line jack Pj of the party desired and restoring the listening key Tk, which opens the low-resistance path across the trunk line and allows the armatures of the relays Lt and Ts to fall back, the former lighting the supervisory lamp Lc and the latter reestablishing the ground connection m. The relighting of lamp Lc is only for a short space of time—until the branch subscriber at station *2* responds—so that the main-board operator does not pay any attention to it, especially as the other supervisory lamp in this cord circuit remains dark. The establishing of the ground contact m by relay Ts completes a new signaling circuit in the branch-exchange end of the trunk; this is due to the operation of relay Tc, which took place when the plug Tp was inserted into jack Pj, the circuit being from battery B_8, through ground–u–ring of jack Pj and plug Tp–relay Tc–B_8. The pulling up of the lower armature of relay Tc opens the battery circuit of the

calling lamp *Tq*, while the operation of the top armature closes the circuit of battery B_s through the ringing lamp *Tn* and back contact of relay *Ts* to the ground side of battery, thus lighting *Tn*. The operator rings the bell at station *2* by closing the ringing key *R*. When the party at station *2* responds, a low-resistance path is again established across the line, and relays *L t* and *Ts* are operated, thereby causing the lamps *Lc* and *Tn* to be extinguished. This condition is maintained during conversation; it should be noticed that station *2* is receiving battery current for talking from battery B_1 at the main exchange.

42. Disconnection.—When the parties are through talking and hang up their receivers, the supervisory lamps *Lc* and *A l* in the main-exchange cord circuit are lighted, which, being the usual signal for disconnection, allows the local operator to immediately pull down the connection. Hanging up the receiver at station *2* deenergizes the relay *Ts*, thereby closing the ground contact *m*, and relighting the ringing lamp *Tn*. The branch operator has hardly time to notice this lamp before the regular disconnect lamp *Tq* lights, notifying her that the main-exchange operator has disconnected. When the latter operation takes place, the polarity of the trunk line is reversed to its normal condition by the falling back of the armature of the cut-off relay *T*, thereby reestablishing the line signaling circuit. The reversing of the polarity of relay *Tb* opens the contact at *e* and closes contact *d*, thereby completing the circuit from battery B_s through ground-*m*-*d*-*r*-closed contact *x*-disconnect lamp *Tq*-battery. The disconnect lamp *Tq* is thus lighted and remains in this condition until the trunk circuit is pulled down, thereby breaking the battery circuit through relay *Tc*, which releases its armatures and thus opens the circuit of the lamp *Tq*.

43. Call From Branch Subscriber for Main Subscriber.—When a branch-exchange subscriber calls for a main-exchange subscriber, the private branch subscriber, station *2*, calls in the regular way and is answered by the

branch operator who inserts the answering plug *P* of a regular branch-exchange cord circuit into the line jack *Pj*. Finding that the call is for a main-exchange subscriber, the operator requests station *2* to hang up the receiver, stating that she will call when the desired party is obtained. The branch-exchange operator pulls out plug *P* and closes the trunk listening key *Tk* which establishes a low-resistance path across the line, thereby allowing sufficient current to flow through the trunk circuit to operate the line relay *Tm* and through it the line lamp *Tl*. The main-exchange operator treats this call the same as that of any regular line and establishes the connection with the desired subscriber, station *1*, in the regular manner. When the private-branch-exchange operator obtains the desired party at the distant telephone, she immediately inserts the calling plug *Tp* of the trunk into the jack *Pj* and rings station *2*.

44. Holding Coil.—The trunks may be held without displaying the disconnect signal in the cord circuit at the main exchange by throwing the key *Th*, which connects a 500-ohm retardation coil *Ti*, called a **holding coil**, across the circuit, thereby allowing the operator to restore her listening key *Tk* so as to attend to other signals at her board. The throwing of the key *Th* closes a local circuit containing the battery B_s and the red guard lamp *Tv*, which serves as a signal to the operator that she is holding a trunk circuit.

The advantage of this trunk is that it can be used for night service when the private-branch-exchange operator is not in attendance, by opening a switch at *v*, near the battery B_s, and thus cut the private-exchange battery from all circuits and prevent unnecessary waste of current. Plugs are inserted in such lines as desire this night service, which are then operated substantially the same as the regular main-exchange lines.

OPERATION OF SIMPLE TRUNK CIRCUIT

45. The second, or simpler, scheme of trunking to private-branch exchanges requires the use of a branch-exchange cord circuit to complete the connection. This gives the branch-

exchange operator more responsibility and slightly more work to do, but as she usually has plenty of time, no objection can be had on this score. As in the case of the more complicated branch-exchange trunk, this trunk line terminates at the main exchange in the same way as a regular subscriber's line, except that the tip and sleeve are reversed at the distributing frame. At the branch-exchange end, this trunk terminates in a drop *D* and jack *J*, the former being bridged across the line with a 2-microfarad condenser in series with its winding so as to prevent the flow through it of direct current from the main-exchange battery.

46. Main Exchange Calling Branch Exchange. If station *1* wishes to converse with station *2* at the branch exchange, the call is treated by the main-exchange operator exactly as for the more complicated trunk, only that it is necessary to ring out over the trunk after inserting the calling plug *Lp* into the multiple-trunk jack *Mj*, the same as in calling a regular subscriber. This ringing current passes through the condenser and drop *D*, causing the latter to release its shutter. The branch-exchange operator answers this signal by inserting into the trunk jack *J* the answering plug *P* of a regular cord circuit; and after obtaining the desired information from the subscriber at station *1* calls the desired private-branch station *2* in the regular way.

Inserting the plug *P* in the trunk jack *J* extinguishes the supervisory lamp *Lc* in the local cord circuit at the main exchange because current flows from B_1 through *y*–ground–*z*–cut-off relay *W*–sleeve side of circuit–relay *Ls*–B_1, thus causing relays *Ls* and *W* to attract their armatures, thereby allowing current to flow from $+B_1$ through relay *L t*–*c*–*a*–tip side of plug *Lp* and jack *M*–sleeve side of jack *J* and answering plug *P*–one winding of relay *Pe*–B_2–other winding of *Pe*–tip side of *P* and *J*–sleeve side of *M* and *Lp*–relay *Ls*–B_1; the batteries B_1 and B_2 are, consequently, in series. The reason for the reversal of the tip and sleeve of the trunk line is now apparent. If the line were not reversed, the two batteries would act in opposition; and being of the same voltage would

neutralize each other. This would result in not operating the relay Lt of the main-exchange cord circuit, or the relay Pe of the branch-exchange cord circuit, thereby causing the supervisory lamps Lc, Ph, controlled by these relays, to light and remain lighted during the conversation. In this simple trunk system, the private-branch-exchange operator is the first to pull down the connection, she receiving only one disconnect signal Pf due to the hanging up of the receiver at station *2*. The main-exchange operator receives the regular double disconnect signal due to the hanging up of the receiver at station *1* and to the pulling down of the cord circuit at the branch exchange.

47. Branch Exchange Calling Main Exchange. Calls from the branch exchange to the main exchange over this simple trunk are made by inserting the plug P into the trunk jack J, thereby putting the main-exchange battery B_3 in series with the branch-exchange battery B_6 in the circuit B_3–h–p–sleeve of jack J and plug P–one winding of Pe–B_6–other winding of Pe–tip of plug P and jack J–line relay N to B_3. Some current may flow from B_6 through ground from b to p, but this would assist rather than oppose the results desired. The line relay N and supervisory relay Pe are thus operated, thereby lighting the line lamp L and preventing the lighting of the supervisory lamp Ph. The remainder of the connection is made in the regular manner.

48. Night Service.—Branch-exchange lines can be plugged for night service when this trunk is used, by means of a special two-strand cord circuit with plugs at each end. One of these plugs is inserted in the trunk jack J, while the other plug is inserted in the desired line jack Pj. The opening of the inside contacts of these two jacks cuts off all branch-exchange signaling apparatus and leaves a clear metallic circuit from the branch-exchange telephone to the main board, thereby giving the branch-exchange subscribers the same signaling conditions as a regular main-exchange subscriber.

49. Non-Multiple Central-Energy Exchanges.—For small, central-energy, non-multiple exchanges, with or

without trunks to a larger main exchange, the private-branch-exchange line and cord circuits shown in Fig. 27 are used. Mechanical self-restoring signals may be used in place of the line and supervisory relays Lr, Pe, Pd, the lamp signals Ll, Ph, Pf not then being required, and the line signal may be arranged to operate a buzzer as a night alarm.

50. Standard Private-Branch Line and Trunk Circuit.—In Fig. 28 is shown what was called, in 1905,

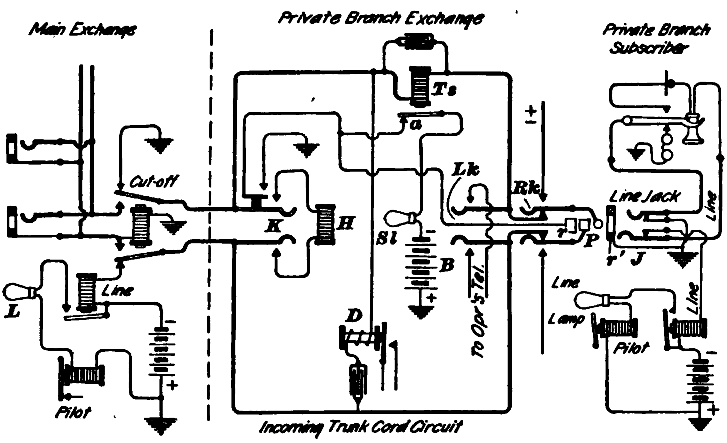


FIG. 28

the **Kellogg standard lamp-signal private-branch-exchange line and trunk circuit.** The trunk circuit ends in a plug at the private-branch exchange and in a regular line equipment at the main exchange. The main-exchange operator calls the private exchange in the same manner as she would ring the bell of a regular subscriber, thereby operating the drop D. The private-branch operator responds by restoring the drop and closing her listening key Lk. After getting the number of the private-branch subscriber desired, the trunk plug P is inserted in the line jack J. Current then flows from B through Sl–a–r–r'–ground, but when the resistance across the line is lowered by the called subscriber taking down his receiver, the relay Ts operates and opens the circuit of the lamp Sl, which then

goes out. At the same time, the tip relay in the calling-cord circuit at the main exchange is energized and the calling supervisory light goes out. When the subscribers hang up their receivers, their respective supervisory lamps light and the operators pull down all connections.

When a private-branch subscriber calls the private-branch exchange, the call, if for another branch-exchange subscriber, is answered with a regular cord circuit; but if for a main-exchange subscriber, it is necessary to remove the answering plug used and insert in its place a trunk plug *P*. This will cause the line lamp *L* at the main exchange to light. The main-exchange operator answers and completes the call in the usual manner.

In order that the private-branch operator may hold the trunk circuit while attending to other calls, there is provided the key *K* and a holding coil *H*. The lamp *S l* will remain lighted, so long as the key *K* is closed, thus reminding the private-branch operator that she is holding the trunk. This is a more simple trunk circuit than the somewhat similar one shown in Fig. 27.

51. Main-Office Connections for Only Some Subscribers.—In some private-branch exchanges, the operating company desires to give main-office connections to only certain private-branch subscribers; for this reason, some private-branch switchboards are arranged so that it is impossible, even with the aid of the operator, for the private-branch subscriber that is not entitled to have main-office connections to get them.

The result is attained in some Kellogg private-branch exchanges as follows: The private-branch lines are connected to one of two sets of connectors, which are wired to separate sets of jacks. As one set of jacks has a larger aperture than the other, only one size of plug will fit certain jacks. The trunk plugs are the larger and will only go in the large jacks. The lines of subscribers having the privilege of main-office connections are connected to the larger set of jacks, and it is nearly impossible for subscribers,

whose lines terminate in the small jacks, to get a trunk connection because the operator cannot insert a large trunk plug in a small line jack. The smaller plugs must also make good connections when inserted in a large jack, or else the lines of subscribers having the privilege of main-office connections must be connected in multiple to both large and small jacks so that the operator's cord circuits, which are provided at both ends with the small plugs, may be used to connect together any two private-branch subscribers.

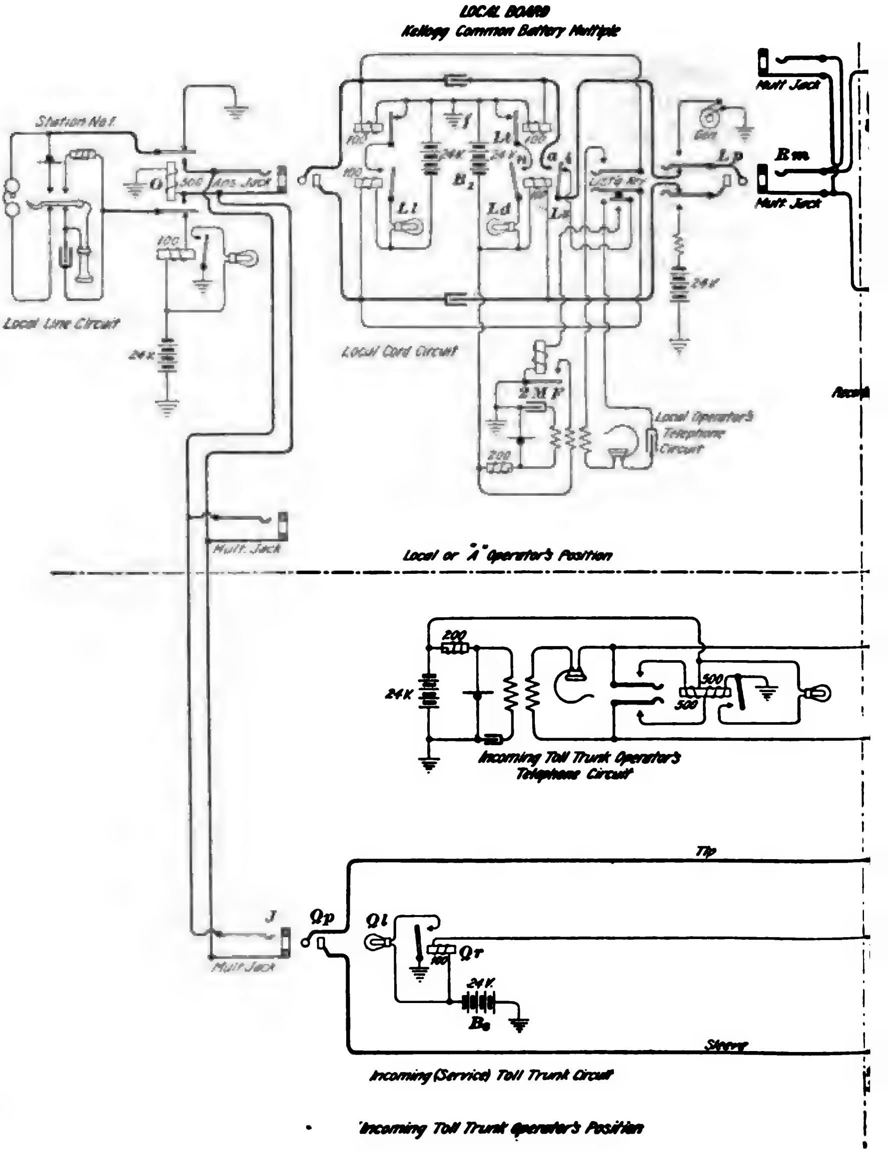
KELLOGG TOLL-SWITCHBOARD CIRCUITS

52. The Kellogg Company employs many toll trunking circuits in their installations, nearly all of which are designed to meet special requirements. But the circuits that follow are as near standard as they can be made and yet represent the most common method of operation. A separate toll board is provided and in most cases is located in the same building as with the local exchange; but in some instances, it is in the outskirts of the city so that the long-distance lines may be brought directly to the exchange building without any great length of cable intervening, as the latter tends to greatly cut down the transmission. The circuits necessary in such cases are special and will not be considered here.

53. Outline of Operation.—In general, the toll board is merely a magneto-multiple switchboard having the long-distance lines terminate in drops and answering jacks at the various operators' positions and with multiple jacks in each section, so that every operator can reach all the toll circuits direct. Located at this board are the *toll operators*, who care for from five to twenty toll lines according to the amount of traffic, and the *recording operators*, who have before them the multiple jacks of the regular toll lines and recording trunk lines terminating in jacks and lamps. These trunk lines extend to the local switchboard and terminate in multiple jacks at each section, where they are located in a space between the answering jacks and regular multiple

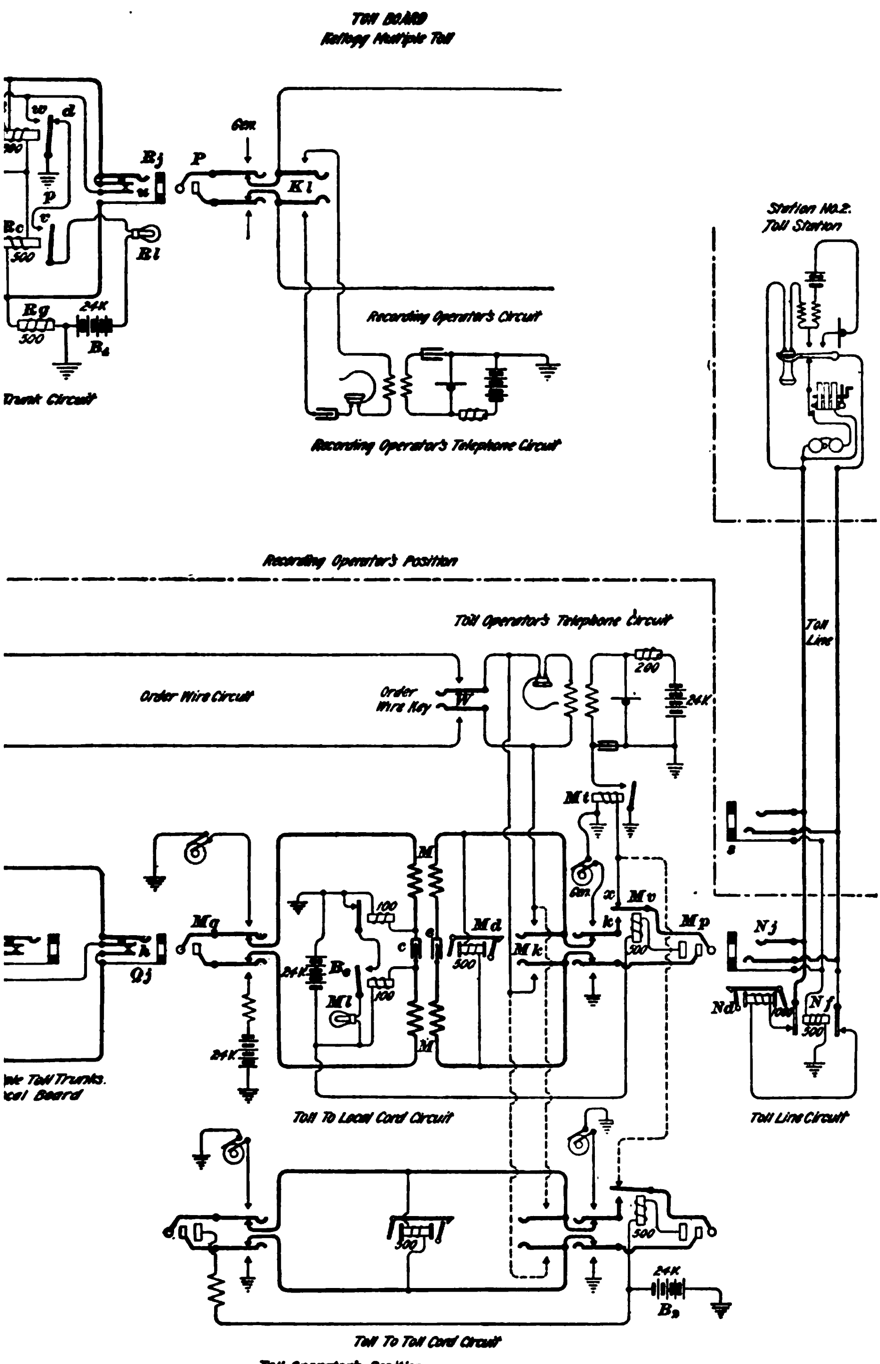
jacks. This allows calls for long-distance connections to be switched by the local-board operators directly to the recording operators, who devote their entire time to receiving and recording such orders on toll tickets, which are passed to the regular toll operators at whose position the desired toll line terminates; the latter operators establish the connections and keep further records of the same. The talking connections between the toll board and the local board are made through a separate set of trunk lines, commonly called *service trunks*, which appear at the toll board in jacks multipled at each section, while the local-board ends terminate in plugs and cords with associated disconnect lamps. Special positions are provided at the local board for these incoming toll trunks, the operators of which simply establish the desired connection by inserting a trunk plug in a regular multiple-jack of the local-subscriber's line. The toll operator rings the local line direct and thereby can have entire control of the connection as well as keep an accurate record of the time consumed in actual conversation. It will be thus understood that the incoming toll-trunk operator at the local board simply establishes connection under order and takes them down when the proper disconnect lamp lights, the latter occurring when the regular toll operator has finished with the circuit.

54. Fig. 29 shows the complete circuits required in making the connections mentioned. The operation will be understood if we follow a toll connection in the regular sequence of its movements. Assuming that the subscriber at station *1* desires to talk with the party at station *2*, who is located in another section of the country, the *A* operator is called in the regular manner. Finding that a long-distance connection is desired, this operator immediately inserts the calling plug *Lp* of a pair of cords into a multiple recording-trunk jack *Rm*, first testing the jack to determine whether it is busy and selecting one that tests free. This test is made the same as for a regular multiple jack. The *A* operator has no more to do with the connection until both



KELLOGG T

FIG.


Toll Board
Kellogg Multiple Toll
Station No. 2.
Toll Station
Recording Operator's Circuit
Recording Operator's Telephone Circuit
Trunk Circuit
Recording Operator's Position
Toll Operator's Telephone Circuit
Order Wire Circuit
Order Wire Key
Toll Line
Toll To Local Cord Circuit
Toll Line Circuit
Toll To Toll Cord Circuit
Toll Operator's Position

CIRCUITS

supervisory lamps light in the cord circuit, which tells her that the cords are to be pulled down.

55. Connecting Local to Recording-Trunk Circuit.—Inserting the plug *Lp* in the jack *Rm* continues the talking circuit to the jack *Rj*, located in the recording operator's position of the toll board. A circuit is also established for current from battery B_1 through the sleeve cord relay *Ls*–sleeve of plug *Lp* and jack *Rm*–500-ohm retardation coil *Rg*–ground and thence back to battery B_1. This operates the sleeve relay *Ls*, opens at *i* the circuit controlling the busy test, and by closing the contact at *a* establishes another circuit for battery B_1 as well as completing the talking circuit through the tip strand of the local-cord circuit. This second battery path is through sleeve relay *Ls*–sleeve of plug *Lp* and jack *Rm*–relays *Rc* and *Rt* at the toll board–tip of jack *Rm* and plug *Lp*–movable spring and contact *a* of relay *Ls*–tip relay *Lt*–B_1. The tip relay *Lt* will thus operate at practically the same time as the sleeve relay *Ls*, so that the supervisory lamp *Ld* will not light. However, the establishing of the battery circuit through the second path will operate relay *Rc* but not relay *Rt*, as its winding is normally short-circuited by the connection through its contact *b* and contact *u* of jack *Rj* to tip conductor of this circuit. The lamp *Rl* associated with the recording trunk jack *Rj* will thus be lighted by current flowing from battery B_4 through the lamp *Rl*–closed contact *v* of relay *Rc*–back contact *d* of relay *Rt*–ground *p* to battery B_4.

The recording operator replies to this signal by inserting plug *P* of her listening cord circuit into jack *Rj*, which opens contact *u*, thereby removing the short circuit around the winding of relay *Rt*, and allowing it to operate. The pulling up of the left-hand spring of this relay introduces a second opening at *b* in this short circuit around *Rt*, while the right-hand spring opens contact *d*, thereby putting out the lamp *Rl* and closing contact *w*, which at present merely connects the short-circuiting conductor now open at *u* and *b* with the ground.

The recording operator switches her talking apparatus into circuit by throwing the listening key *K l* and obtains from the subscriber at station *1* the name and the full address of the party desired as well as his own number and name, and records the same on a toll ticket, which she passes to a regular toll operator. As it usually takes some time for the latter to get the desired party, even when available long-distance lines are not busy, the local subscriber at station *1* is told by the recording operator to hang up his receiver and wait until called. This allows his line to be freed from connecting circuits and used for other business in the meantime.

56. Disconnecting Recording Trunk From Local Circuit.—The removing of the plug *P* from the recording-trunk jack *R j* allows the jack-contact *u* to close, but will not restore the short circuit around the winding of relay *R t* on account of the opening at *b*. However, a low-resistance path is established from the tip of the recording-trunk circuit through *u*–*w*–*p*–ground, which short-circuits the tip relay *L t* of the local cord circuit and causes it to release its armature and light the disconnect lamp *L d*. The path for the current may be traced from B_1 through *f*–ground–*p*–*w*–*u*–tip conductor–relays *R t* and *R c*–sleeve conductor–relay *L s* to battery; the path through *f*–ground–*p*–*w*–*u* to tip conductor practically short-circuits the relay *L t* and hence deprives it of sufficient current to keep it closed.

Hanging up the receiver at station *1* lights the answering supervisory lamp *L l*, thus giving the usual double disconnect signal to the *A* operator, who pulls down the cords and restores the circuits to normal condition. It will be noticed that the *A* operator's work is kept the same as for local connections between subscribers and all unnecessary confusion is thereby avoided.

57. Connecting Toll Cord to Toll Line.—The regular toll operator, on receiving the toll ticket from the recording operator, proceeds at once to obtain the distant party, which is in this case station *2*. She first tests the multiple jack *N j* of the toll line with the tip of the plug *M p* of the toll half of

a toll-to-local cord circuit. If the line is busy, battery B_4 will be connected through a 500-ohm relay and the ring of another plug like *Mp* to the ring *s* of a multiple jack of this line, thus when the tip of plug *Mp* touches the ring of jack *Nj* this current from battery B_4 will find a path from *s* through tip of plug *Mp*–back contact *x* of relay *Mv*–winding of test relay *Mt* to ground. The latter will attract its armature and give the regular busy test. If the line is not busy, the operator inserts the plug *Mp* in jack *Nj* and rings the distant subscriber in the usual manner, closes her listening key *Mk* and waits for some one at station *2* to reply. The insertion of the plug does three things—it disconnects the toll line drop *Nd*, cuts off the busy-test circuit through *Mt*, and closes, at *k*, the tip conductor of the cord circuit. This is brought about by current that flows from battery B_4 through the 500-ohm relay *Mv*–ring of plug *Mp*–ring of jack *Nj*–cut-off relay *Nf* to ground side of battery.

58. Connecting Toll Line to Local Line.—When station *2* responds, the toll operator immediately presses the order-wire key *W* that connects her talking circuit directly with that of the incoming toll-trunk operator at the local, or *A*, board and requests a connection with station *1* which she finds on her toll ticket is the party desiring station *2* over the long-distance circuit. The incoming trunk operator picks up the first idle trunk plug *Qp* of a toll trunk line and inserts it into the multiple jack *J* of the desired-subscriber's line without testing and at the same time repeats back to the toll operator the order, together with the number or name of the trunk line used.

Inserting the trunk plug *Qp* in jack *J* establishes a circuit for the battery B_4 through winding of relay *Qr*–contact *h* of jack *Qj*–sleeve of trunk line–sleeve of plug *Qp*–sleeve of multiple jack *J*–winding of cut-off relay *O* to ground side of same battery. The cut-off relay *O* and the trunk relay *Qr* are both operated, the former clearing the local line from its signaling apparatus, while the latter lights the lamp *Ql*. This lamp serves at this stage of the connection as a guard,

showing to the trunk operator when it is extinguished that the toll operator has gone in on the right trunk line. The toll operator on inserting the plug *Mq* of the local half of the toll-to-local cord circuit used into the multiple jack *Qj* of this toll trunk line, opens the contact *h*, thus clearing the trunk line from all signaling apparatus and extinguishing the lamp *Ql*. The trunk line is now a mere extension of the two-wire circuit of the subscriber's line to the toll board; the operation of the signals in the local half of the toll-to-local cord and the retaining of the cut-off relay *O* in its operated position being the same as previously described for the line and cord circuit of the Kellogg multiple switchboard.

It will be noted that there has been no busy test made by either the trunk or toll operator, it being unnecessary, as the toll operator knows by the condition of the supervisory lamp *Ml* whether the local line is in use or not. If this lamp lights, on inserting the plug *Mq* in jack *Qj*, she knows that the line is free and proceeds to ring the subscriber direct in the usual way. As the local line is extended directly to the toll operator, she has absolute control of the connection, and knows, by the going out of the lamp *Ml*, when the party responds.

59. Disconnection.—The toll operator knows by the lighting of this lamp *Ml* and by the operating of the clearing-out drop *Md*, bridged across the toll half of the cord, just when the conversation is finished, the lighting of the lamp being caused by the subscriber at station *1* hanging up the receiver, while the operating of the drop is caused by the "ringing off" of the subscriber at station *2*. The actual time elapsed during conversation is thus obtained and recorded on the toll ticket with a considerable degree of accuracy.

When the toll operator pulls down the toll-to-local cord circuit, the closing of contact *h* in jack *Qj* reestablishes the circuit of the battery B_8 through relay *Qr*–contact *h*–sleeve side of incoming toll trunk–sleeve of plug *Qp*–sleeve of multiple jack *J*–winding of cut-off relay *O*–ground side of

battery. This battery current keeps the cut-off relay *O* in its operated position and causes relay *Q r* to attract its armature, thereby lighting the trunk lamp *Q l*, which now serves as a disconnect signal. The incoming-trunk operator thereupon pulls down the connection, restoring the circuits to their normal condition.

60. The repeating coil *M* of the toll-to-local cord circuit serves to disassociate the exchange battery B_s and its permanently connected ground from the toll half of the cord, thereby assuring immunity from disturbances due to this source when connection is had with a long-distance line. The condensers *c* and *e* serve as paths for the voice currents through each half of the repeating coil. Condenser *c* also keeps the middle of the local half of the repeating coil open to the flow of direct current from battery B_s, which would otherwise be short-circuited with respect to the tip and sleeve of the cord. The repeating-coil circuit, which shunts the clearing-out drop *M d*, has its impedance to the low-frequency current used in ringing off greatly increased by the condenser *e*; consequently, the ringing-off current, or at least enough of it, is forced through the clearing-out drop to operate it.

61. The **toll-to-toll cord circuit** shown at the toll operator's position is used for connecting two toll lines together and is simply a magneto-cord circuit with a relay in its third strand for cutting off the busy-test connection, operating the same as relay *M v* in the toll-to-local cord circuit. One or more of these toll-to-toll cords in each operator's position are usually supplied with a repeating coil so as to metallically disassociate any two connected lines if they appear noisy through induction when connected by a continuous and through pair of conductors.

PARTY-LINE SYSTEMS
(PART 1)

NON-SELECTIVE PARTY LINES

1. Classification.—A telephone line connecting two or more stations with the central exchange is called a **party line.** This term is used in distinction from **private line,** which may be defined as a line connecting a central office with one subscriber only, or one subscriber with one other subscriber. Party lines may be divided into two general classes: the **non-selective signaling system,** in which all the bells ring when a signal is sent to any one on the line; and the **selective signaling system,** in which means are provided for ringing the bell of any subscriber without disturbing the others on that line.

On non-selective signaling systems, a code of audible signals is employed to enable the parties at the various stations to distinguish their calls from those of the other stations. These codes usually consist of a various number of rings or various combinations of long and short rings, so that a party may at once, by sound, tell whether or not his attention is desired at the instrument.

2. There are two general methods of arranging instruments on non-selective party lines. One is to place all the instruments in series in the line wire, and the other is to connect them in multiple across the two sides of the line circuit. The first of these systems is called the *series-system*, and the second the *multiple*, or *bridging*, *system*.

THE SERIES-PARTY LINE

3. Arrangement of Instruments on Series-Lines. The general arrangement of instruments on a **series-party line** is shown in Fig. 1. The line wire is cut at each station and the two ends so formed are connected with the two line binding posts on the instrument; thus the various telephones *1*, *2*, *3*, *4*, *5*, and *6* are connected in series in a line wire *L*, the terminals of which are grounded at the points *G*, *G*. This is a *grounded series-line*, because the return is made through the ground. It would be termed a *metallic-circuit series-line* if the return circuit were made through a separate wire instead of through the ground, as shown in this figure.

4. Circuits of Series-Instruments.—The instruments used on a series-line are called **series-telephones**.

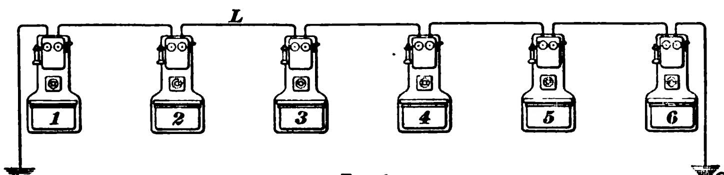


FIG. 1

In this form of instrument, the ringer and generator are connected in series between the two line binding posts of the instrument and the generator is normally cut out by means of the shunt. When the receiver of any instrument is raised from its hook, the circuit containing the generator and call bell is opened, while the talking circuit, which contains the receiver and the secondary winding of the induction coil, is closed between the same two binding posts. It therefore follows that when two subscribers on such a line are talking, the circuit through their instruments will be through the talking apparatus, while that through all the instruments not in use will be through the calling apparatus. The generator armatures are short-circuited when not in use, because they have so high a resistance and impedance that it would be difficult to talk and ring through a circuit containing many of them. The ringer magnets in series-telephones should

be of low resistance, in order that they may not unduly obstruct the passage of the voice currents.

5. Objections to Series-Line.—On a line having six instruments, such as that shown in Fig. 1, if subscribers *2* and *5* were talking, the circuit would be completed through their talking apparatus and through the ringer magnets of instruments *1*, *3*, *4*, and *6*; this inclusion of the ringer magnets of all idle instruments in the talking circuits is a necessary evil in the series-system, inasmuch as these magnets must at all times, when the instrument is not in use, be left in the circuit in order that each instrument may at any time receive a call. The evil may be reduced to a minimum by winding the magnets to a low resistance and cutting out the generators, as already stated; but even then series-instruments are not capable of giving the best service.

Besides this, such a line is subject to serious disturbances caused by induction from other wires or by earth currents due to differences in potential of the earth at the two ends of the line. Inductive troubles on such a line may be largely reduced by using a complete metallic circuit, which will also, if properly insulated, do away entirely with earth currents. This, however, does not remove the evil effects of the ringer coils placed directly in the talking circuit, and only partly relieves the troubles due to induction from other wires, for it has been found that a proper balance can seldom be obtained between the two sides of a metallic circuit used for a series-party line.

So far as the actual ringing of bells is concerned, as many as forty instruments may be placed on a line, but this renders the talking exceedingly poor. Besides this, there is always an incessant ringing of bells and a consequent annoyance and confusion of signals. As a rule of good practice, not more than ten instruments should be placed on a series-line, though, of course, conditions sometimes render a greater number necessary.

6. Condensers and Non-Inductive Resistances on Series-Party Lines.—The operation of series-party lines,

having a large number of stations, can often be improved by connecting in parallel, with the bell only, either a $\frac{1}{2}$- to $\frac{3}{4}$-microfarad condenser or a non-inductive resistance of three to five times the resistance of the bell. The resistance is preferably made of German-silver wire. In either case, enough of the ringing current will pass through the bell to ring it, while the talking current will more readily pass through the condensers or non-inductance resistances at the stations not in use than through the bell coils which have considerable inductance. While either method greatly improves the talking circuit, both are objectionable since both condensers and non-inductance resistances are quite susceptible to injury from lightning discharges. This injury is often first noticed by a deterioration of the talking circuit and can be ascertained only by a visit to the subscriber's house. The non-inductive resistance takes some current from the bell and a generator that would ring an 80-ohm bell through 10,000 ohms will not ring the same bell shunted by 300 ohms through more than about 4,000 ohms. A condenser, while probably more satisfactory, requires so much room that it can seldom be placed inside a telephone box not made to hold it.

7. Series-Generators.—The generators for series-lines are usually wound with a large number of turns of rather fine wire, for it is desirable for them to generate a high voltage with a comparatively small current. The greater the number of series-bells in a line, the greater should be the electromotive force produced by the generator to give the same current. The ordinary generator for this purpose is wound with No. 35 or No. 36 B. & S. gauge, single, silk-covered wire to a resistance of about 600 ohms. The ringers are frequently wound with No. 31 wire to a resistance of 120 ohms, but better results may be obtained by winding them with No. 30 wire to a resistance of from 60 to 80 ohms.

THE BRIDGED PARTY LINE

8. Arrangement of Instruments on Bridged Line. Nearly all the early party lines were operated on the series-plan already outlined, but in 1890 Mr. J. J. Carty patented the **bridging, or parallel, method** of connecting telephones with the line circuit, which obviates many of the difficulties inherent in the series system.

Fig. 2 shows the telephones *1, 2, 3, 4, 5, 6* bridged between a line wire *L* and the ground *G*. The instruments used on this circuit are called **bridging telephones.** Their ringer magnets are bridged permanently between the two line binding posts, thus keeping this circuit closed whether or not the receiver is removed from its hook. In an entirely independent circuit, bridged between the same two binding posts, is the calling generator, the circuit of which is

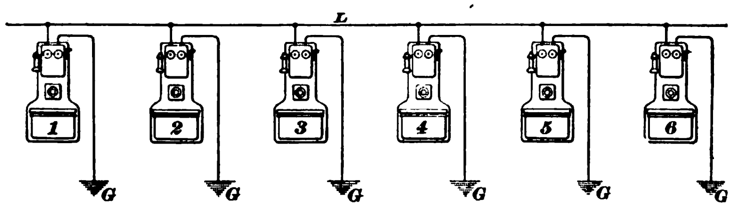


FIG. 2

normally held open either by a push button or by an automatic circuit closer operating in much the same way as the automatic shunt in the series-telephone. Neither of these circuits is controlled in any way by the hook switch. A third circuit in each telephone is normally held open by the hook switch and is closed only when the hook is released from the weight of the receiver. This circuit contains the receiver and the secondary winding of the induction coil in series and is like the other two circuits connected between the line binding posts. With the instruments connected between the line wire and ground, as shown in Fig. 2, whenever the generator at any instrument is operated, the current from it will pass in multiple through all the ringer magnets on the line.

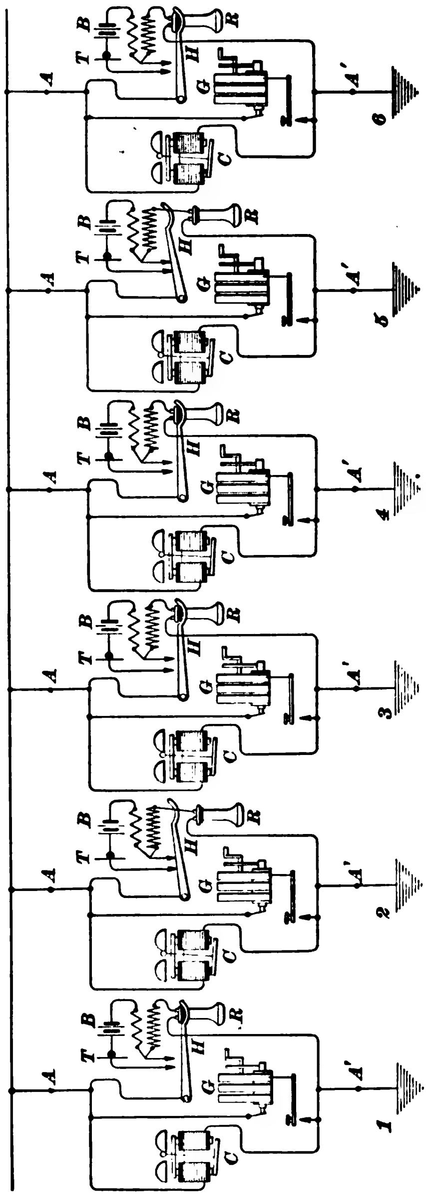


FIG. 3

9. Operation of Bridging System. The operation of the bridging system may be more readily understood by considering Fig. 3, in which the circuits of six stations are shown connected in multiple between a line wire and the ground. The circuits in this diagram are arranged to show the existence of the three bridged circuits between the two binding posts A, A' of each instrument. When one station desires to call another, the generator circuit is closed either by a pressure on the push button, or, in better instruments, by an automatic device on the crank-shaft, while the generator is operated in the ordinary manner. The current from the calling instrument will divide; part of the current produced by the generator at any station will flow through the ringer C at the same

station, and part will pass in multiple through all the other ringers on the line. A certain number of rings will be given in order to designate the party for whom the call is intended, and will be answered by one ring, after which both parties will remove their receivers from the hooks in order to converse.

10. In Fig. 3, the receivers at stations *2* and *5* are removed from the hooks to permit conversation between them. At all the other stations, the receivers are supported by the hooks, showing that these instruments are not in use. The voice currents generated at station *2* by the operation of the transmitter will pass over the circuit formed by the line wire and the ground to the instrument at station *5*, through the talking apparatus of which they will pass, actuating the receiver in the ordinary manner. As the ringer magnet *C* at each station is also connected between the line wire and ground, each magnet will form a path for these voice currents between the line wire and ground. The leakage through these bells would be a very serious matter were it not that they are wound to a very high resistance and in such a manner as to present a great amount of impedance to the passage of the rapidly fluctuating voice currents. By this means, the leakage of the voice currents through these ringer magnets is rendered so small as not to be noticeable and therefore they produce no undesirable effect on the talking efficiency of the line.

11. Ringers.—The high retardation of the ringer coils is attained by using a somewhat longer spool than in the ordinary ringer, and winding it with a large number of turns of wire to a high resistance. The best construction for a 1,000-ohm ringer is to wind it with No. 33 single, silk-covered magnet wire. At one time, many companies, in order to obtain the desired resistance in a smaller space, wound the magnets with No. 38 wire to a slightly higher resistance, sometimes to 1,600 ohms. This, however, does not give as good results as the use of the No. 33 wire, because a No. 33 wire having a resistance of 1,000 ohms will be very much

longer than a No. 38 wire having the same resistance. The No. 33 wire will, therefore, when coiled on a magnet core, give a much larger number of turns on the magnet, and this is what gives the magnet a high impedance. Some recommend the winding of a 1,000-ohm bell with 12,950 turns of No. 36 B. & S. wire.

12. Bridging bells are usually wound to a resistance of 1.000, 1,200, 1,600, and 2,500 ohms, and occasionally as high as 5,000 ohms. An arrangement of the bell circuits that is said to be very satisfactory consists in connecting a 2-microfarad condenser in each bell circuit on a bridging party line. This is only necessary and advisable where there are a large number of bridging telephones on the same line circuit or in central-energy systems.

13. Bridging Generators.—Generators for bridging instruments should be designed to produce a large amount of current rather than a high electromotive force, because they may have to supply current for a number of bells arranged in multiple. It frequently occurs, also, that a high voltage as well as a large amount of current is needed, so that each subscriber will be able to call all the others on the same party line. This is especially the case on long and heavily loaded iron lines, where a high voltage is needed to force the current through the line wire to the more remote instruments. It not infrequently happens that generators designed for a series-line are rewound with a larger wire in the hope that they will operate successfully on very long bridged lines. As a rule, these attempts are unsuccessful, because, when so rewound, the generators do not generate sufficient electromotive force to send enough current to the distant parts of the line. Under severe conditions, the ordinary series-generator is not capable of producing sufficient power to meet the conditions, and the only remedy is to rebuild the line or equip it with generators made by some reliable firm, according to the most effective designs.

Some bridging generators are wound to a resistance of 350 ohms with No. 33 B. & S. wire. The Bell Companies

use a generator wound to a resistance of 250 ohms. One manufacturer claims that his five-bar bridging generator will ring forty bells simultaneously over 50 miles of No. 12 B. W. G. iron wire.

14. Induction Coils.—The mistake is often made of using 500-ohm induction coils on bridged lines. This practice tends to make the induction coils at the two instruments in use present a very high impedance to voice currents, and to thus obstruct their passage through the talking circuits

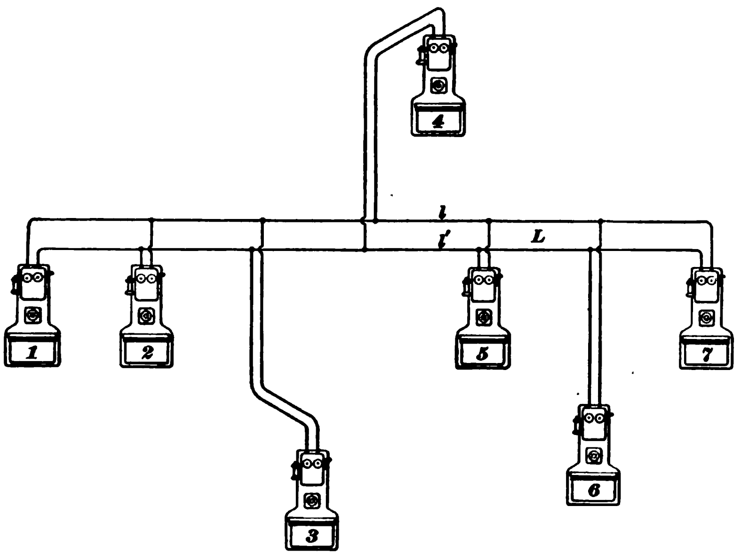


FIG. 4

at these two instruments, which is exactly what is not desired. It is much better to use low-wound induction coils, so that the voice currents sent over the line wire will find a more ready path through the talking circuit of the station receiving at that time than through the call-bell bridges at the other stations. The use of induction coils having secondary windings varying from 14 to 100 ohms is increasing, and in no place are they of greater service than on bridged lines.

15. A metallic circuit L with seven stations bridged across the two line wires l, l' is shown in Fig. 4. The internal

connections of each instrument are exactly the same as shown in Fig. 3. The great advantage of this arrangement is that the adding of an instrument does not tend in any way to destroy the balance of the line. When branches of considerable length are run off from the main line, as in the case of instruments *3*, *4*, and *6*, each line is in itself thoroughly balanced, and the two sides of the line circuit may be transposed as frequently as desired in order to render the line absolutely quiet. The bridging system is now used very extensively.

There is one distinctly beneficial effect obtained by the bridging system. The numerous cross-connections through the bells tend to free the line from electrostatic charges, and thus diminish indistinctness or cross-talk due to the capacity of the lines. This is of considerable importance where a ground return is used, because the cross-connections allow disturbances due to earth currents and other external sources to escape to earth without having to pass through all the telephones. Consequently, a grounded circuit with several bridging-bell connections may even furnish better service than it would with only one telephone station on it.

16. Modifications of Bridging System.—There are several modifications of the bridging system, in one of which the bell magnet is cut out when the receiver is removed from the hook. This is accomplished by connecting the bell between one binding post of the instrument and a bottom contact of the hook, the circuit being completed, when the hook is down, through the lever to the other line binding post. The operation of this system is identical in every respect with the original bridging system, where the bells are permanently bridged between the binding posts. It has the slight additional advantage of making one less bridge or leak circuit across the line for the talking currents, but the corresponding disadvantage of an additional contact on the hook switch.

CONNECTION OF PARTY LINES WITH SWITCHBOARDS

17. Much trouble is frequently caused by connecting party lines with switchboards in an improper manner. A series-party line should be brought into the exchange in the same manner as any other line, the line drop being of approximately the same resistance as the ringer magnets, i. e., about 80 ohms, and included directly in the circuit of the line. It should be so arranged with respect to the jack as to be cut out of circuit on the insertion of a plug, in order that it will not be necessary to talk through it.

Under ordinary circumstances, a bridged line should have the drop connected directly across the two sides of the circuit in the same manner as the ringer magnets at the various instruments. The drop should be so wound as to have a high resistance and impedance, and usually should have the same resistance as the ringer coils on the line. If, however, a tubular drop is used, a resistance of 500 ohms will usually be found sufficient, the iron core and shell increasing the impedance of the magnet to a sufficient extent to prevent the undue short-circuiting of voice currents. The drops may be left permanently bridged across the line in multiple with the jack, but the presence of this permanent bridge cuts down the efficiency of ringing over the line to the distant stations. It is usually better to so arrange the drop that it will be cut out of circuit when a plug is inserted in the jack. When left permanently in the line, however, it may serve as a clearing-out drop.

CENTRAL CHECKING TELEPHONES

18. Calling in One Direction.—On party lines terminating in an exchange, it is frequently desirable to so arrange the apparatus that the various stations cannot call each other, but can call the central office. This may be accomplished on a bridged line by winding the switchboard drop to a very low resistance, and so arranging it as to be cut out when a plug is inserted. As a result, this drop will

practically form a short circuit between the two sides of the line, and nearly all the current sent out from any subscriber's generator will flow through it instead of through the high-resistance bells. This plan gives good results on medium or short lines, but when used on very long lines, the resistance of the line wire may be sufficient to shunt the current sent from the stations farthest from the central office through some of the ringer magnets nearest to them, thus causing them to ring. In order to prevent this, some companies use bells wound as high as 2,500 ohms.

19. A more satisfactory method is to so arrange the polarized ringers that they will respond to currents in a certain direction only, and to provide commutators on the shafts of the generator armature at the subscribers' stations so that the generator will send out pulsating current in one direction only, that direction being opposite to that required for ringing the polarized bells. The switchboard drop bridged across the line at central may be of the non-polarized type and adapted to be thrown by currents in either direction. The central-office generator may be of the ordinary type, giving alternating currents which, when sent over the line, will operate the bells of all the subscribers.

In the operation of this system, no subscriber can obtain a conversation with any other subscriber without the full knowledge of the operator, because the currents sent out by any subscriber's generator are in the wrong direction to ring the bells of any other subscriber. Such currents, however, will throw the switchboard drop and attract the attention of the operator, who can then call up the party desired, whether on the same or another line, in the ordinary manner. If the party desired is on the same line, the calling subscriber must hang up his receiver while the operator rings, giving the proper code ring for the subscriber desired.

20. Biased Bells.—One method of arranging the armature of a polarized bell, so that it will be rung by current impulses in one direction only, is to attach a spring to one end of the armature in such a way as to normally pull it

toward one pole when there is no current through the coils; but this spring must be weak enough to allow the armature to be drawn toward the other pole when the current flows in the proper direction. It is evident that if the end of the armature is held toward the negative pole, no effect will be produced on the bell hammer by currents flowing over the line, which would tend to increase the strength of that negative pole, because the magnetism so generated would tend only to pull the armature closer to the pole against which it already rests. By attaching the spring to the opposite end of the armature, the bell may be rung by currents flowing in the opposite direction. Bells arranged in this manner are said to be **biased** and are extensively used.

21. Telephone instruments for use on party lines and arranged to operate only the exchange drop are sometimes called **central-checking** or **silent-signaling telephones.** This arrangement prevents all the bells from ringing and the curious from knowing and hence listening on the line every time the exchange is called, and it enables a record to be kept of the number of calls made by each subscriber. In Fig. 5 is shown the wiring of a Dean central-checking bridging telephone. Normally, the direct-current generator *DCG* is on open circuit and the bell is across the line posts *T*, *S*. When the handle is turned, the bell and generator are in parallel and both are connected across the line posts through a contact on the hook switch. The bell requires an alternating current to ring it.

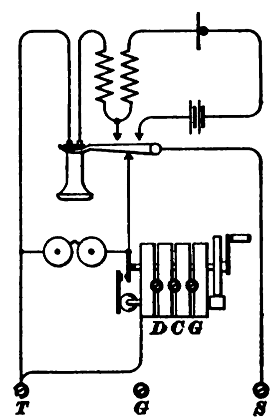


FIG. 5

22. In Fig. 6 is shown the wiring used in Kellogg bridging telephones having a direct-current magneto-generator. Normally, the bell is connected across the line posts *S*, *T*, and the generator circuit is open; when the generator handle is turned, the bell is cut out and a direct current is produced

that will operate an exchange drop but not the ordinary polarized bells bridged across the line.

23. Trouble Due to Unreplaced Receivers.—The failure of subscribers to replace their receivers when they are through talking has always been a source of trouble on toll and rural lines across which a relatively large number of instruments are connected. This not only prevents their being called, but in some cases makes it impossible to ring others on the same line. Also, where parties have a tendency to listen in, it is difficult to ring a party if he does not respond to the first ring, because other parties take down their receivers before he can be rung up again. The failure of the bell to ring is due to the fact that so much of the ringing current leaks through the various receivers that enough current is not left to ring the bells. The best remedy for this trouble consists in connecting a ½- or 1-microfarad condenser in series with the secondary circuit of the telephone, that is, between the receiver and the line. Such a condenser will offer a slight resistance to the voice currents, but a very much higher resistance to currents of the lower frequency delivered by the ordinary hand generators, so that if station *1* were ringing station *3*, and the receiver should be removed from the hook at station *2*, very little of the ringing current would be lost through the secondary circuit of station *2*. This is the method most generally used, and is better than winding the secondary of the induction coil to a high resistance.

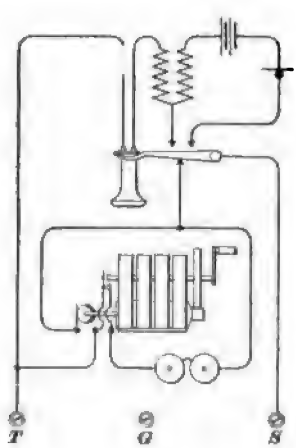


FIG. 6

The addition of a ½-microfarad condenser connected in series with the receiver itself is quite effective in preventing the shunting action due to the receiver being left off the hook. However, it does not always entirely cure the trouble,

as it may sometimes interfere considerably with transmission. A preferable way, in some cases, is to connect a push button in series with each receiver, so that it will be necessary for the subscriber to press the push button while conversing, in order to keep the secondary circuit closed. The circuit is automatically opened as soon as the subscriber releases the push button. Although subscribers might complain that such an addition was an annoyance, the reply could be made that if the subscriber would be careful to replace the receiver it would not have been necessary to insert the push button.

RING-THROUGH OR RING-BY TELEPHONES

24. To obviate the difficulty of ringing the bells when one or more receivers are off the hooks, many manufacturers make special bridging instruments called **ring-through, ring-by,** or **sure-ring telephones.** Fig. 7 shows that the wiring for the Dean ring-through telephone is the same as for the Dean standard bridging telephone with the exception of a condenser that is included in the receiver circuit, so that parties listening in on the line will not prevent the bell of another party on the same line from being rung. This is said to hold good on heavily loaded lines when practically all the receivers are off the hooks. Normally, the generator is short-circuited and the bell is connected across the line binding posts *T*, *S*. While in use, the generator is connected across the line binding posts and the bell is short-circuited. The generator-bell circuit is cut out when the receiver is off the hook.

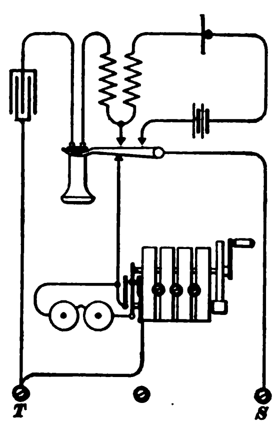


FIG. 7

25. In Fig. 8 is shown the Kellogg wiring for a ring-through bridging wall telephone with a condenser *C* in the receiver circuit. *B R* is the bridging ringer and *H G* the hand

generator. In Fig. 9 is shown the wiring for a similar desk telephone. This arrangement gives the least possible number of conductors a, b, c, d in the flexible cord running into the base of the desk stand. As shown, the induction çoil is located in the desk stand, but it could be placed elsewhere without requiring any more flexible conductors. In both the wall and desk telephones, the hand generator HG is normally on open circuit; when the generator handle is turned, the armature is connected across the line binding posts T, S and the bridging ringer BR is cut out. The generator-bell circuit is open when the receiver is off the hook.

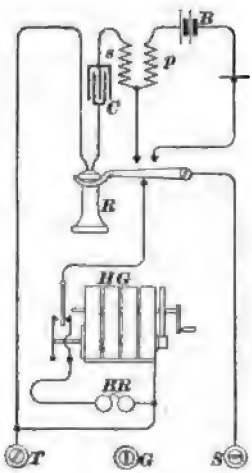


FIG. 8

26. Sure-Ring Telephone.—The connections of the **Stromberg-Carlson sure-ring bridging** telephone, for use on toll or heavily loaded non-selective rural party lines, are shown in Fig. 10. They are the same as in ordinary bridging telephones with the exception that a 1-microfarad condenser is connected in series with the receiver when the latter is off the hook. When the receiver rests on the hook, the condenser is short-circuited and the receiver circuit is opened. The short-circuiting of the condenser prevents it

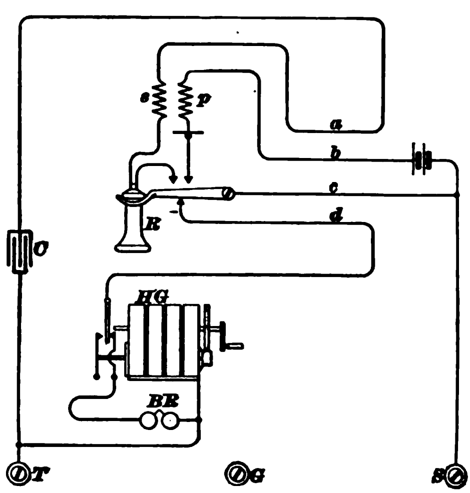


FIG. 9

from being damaged by lightning discharges. The condenser offers considerable impedance to the ringing current on account of its low frequency, and it is claimed that on a bridging party line with twenty telephones it is possible to ring the entire twenty telephones with all the receivers off the hooks. To the talking current, which has a very high frequency, the condenser offers but little impedance and the talking circuit is claimed to be as efficient with the condenser as without it. The addition of the condenser is said to increase the cost of this telephone instrument about 50 cents. The generator armature is normally short-circuited through contact springs *n e* and the connection between the generator and line binding post *S* is open at *a*; when the generator handle is turned, the generator armature is no longer short-circuited through *n e*, for *n* is pushed against *a* so that one end of the armature is connected through the insulated pin in the shaft and the spring *n* to spring *a*; hence, the armature is connected across the line binding posts *T*, *S*.

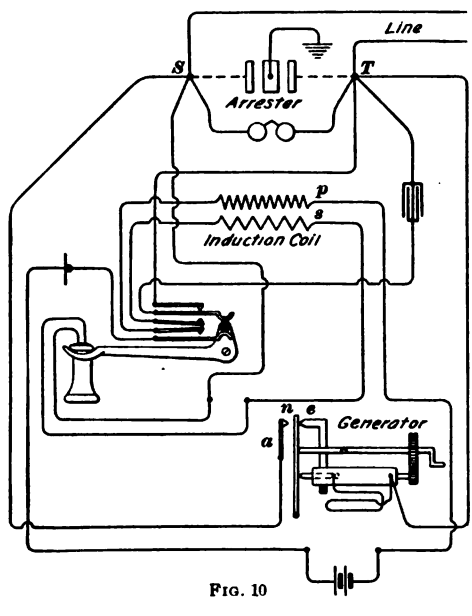


FIG. 10

27. The **ring-through induction coil** made by Kusel & Kusel Company is connected in their telephone instrument as shown in Fig. 11. *L*, *L'* are the line binding posts to which are connected the lightning arrester *L R* and generator terminals. An automatic device keeps the generator normally on open circuit. The bell is connected through contacts on the

hook switch that are closed only when the receiver rests on the hook. The transmitter *T*, primary winding *p* of the induction coil, and battery are connected, as usual, in series when the receiver is off the hook. The secondary of the induction coil consists of two windings *s*, *s'*, one end of each being open. One end of *s* is connected through the receiver to the line *L*, and the other end of the other winding *s'* is connected through the hook-switch contacts to point *e* and the other line wire *L'*. The circuit of this secondary being open, the action of the coil depends on the fact that the line wire, receiver, and coil possess considerable electrostatic capacity. The rapidly alternating voice currents from the line charge and discharge through one winding *s'* of the secondary, thereby producing, probably by a combination of electrostatic and electromagnetic induction, similar voice currents in the other secondary winding *s* and receiver circuit. When talking, the variable current passing through the

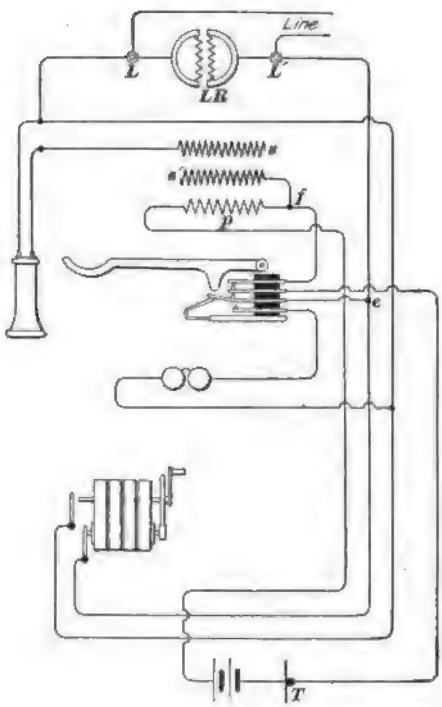


FIG. 11

primary winding *p* will induce an electromotive force in both secondary windings *s*, *s'*, and these two electromotive forces always tend, on account of the direction in which the secondaries are wound on the iron core, to send currents in similar directions at the same instant through the line circuit. While the winding *s* tends to send an impulse or electrostatic

charge toward the receiver, the windings s' tends to suck in a similar charge, or we may say it tends to send out to its line wire a negative impulse, or charge, of equal strength.

That coils would act in this manner has been known for a long time, but no practical use seems to have been made, heretofore, of this knowledge, probably because the arrangement is not apt to be very efficient. This instrument was designed for use on long rural party lines where a large number of instruments are bridged across one circuit. In this instrument, the receiver circuit is open, even if the receiver is left off the hook, and to the low-frequency ringing current the impedance of the open secondary of the induction coil is so great that there is no difficulty in ringing all the other bells on the circuit, even with one or more receivers off their hooks.

NON-INTERFERING TELEPHONES

28. Fig. 12 shows the wiring used by The Dean Electric Company for so-called **non-interfering service.** By pressing the button *k*, central can be signaled without disturbing other parties on the same line. With the button in its normal position, subscribers can call each other in the regular way without throwing the drop at central. Like a regular bridging telephone, it is necessary to listen on the line before ringing to see if it is in use, and, when signaling, the receiver hook should be down. Normally, the generator armature is short-circuited and the bell is connected across the line binding posts *T*, *S*. Turning the generator short-circuits the bell and connects the generator across the line wires so that an alternating current flows through the two line wires and all the bells in multiple

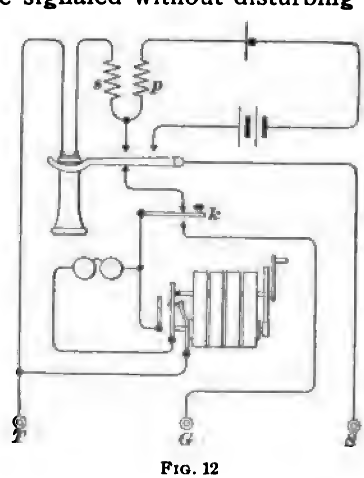


FIG. 12

across the line; but if the key *k* is pressed, the generator is connected between line *T* and the ground *G*, so that an alternating current flows in the tip side of the line, exchange drop, and ground. In this arrangement the circuit is free

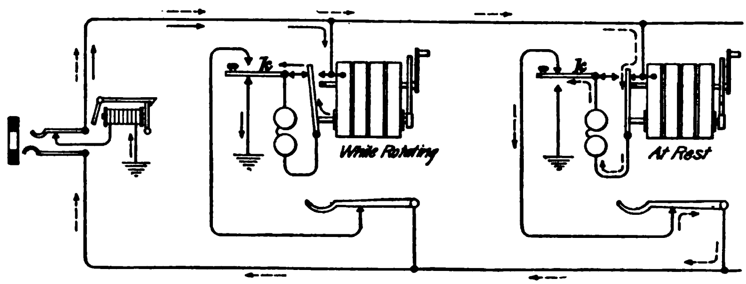


FIG. 13

from grounds, when a plug is inserted in the jack, the same as when used as a toll line.

Fig. 13 shows the signaling circuits of a bridging line provided with these telephones. The line drop winding at the exchange is connected between the tip of the line and ground. To operate the drop, the key *k* at one station is pressed while the generator handle is rotated. The full arrows show the path taken by currents thus produced. The dotted arrows show the path of ringing currents through the line and one telephone when produced at the exchange or at another telephone whose key *k* is not pressed.

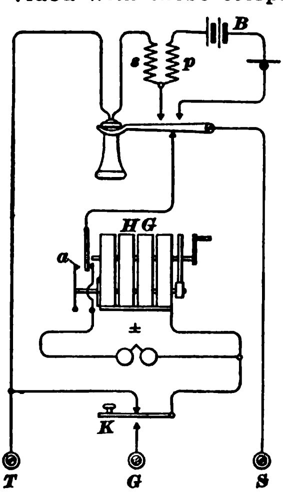


FIG. 14

29. In Fig. 14 is shown the wiring of a Kellogg bridging telephone with a grounding key. Normally, the alternating-current generator is cut out of the circuit by its own automatic device, which opens the armature circuit at *a*, and the bell is bridged across the line wires. When the generator is turned, the bell circuit is opened and an alternating current

is produced, which flows through the two line wires, unless the grounding key K is pressed, in which case the generator is connected between the ground and the line wire S.

30. Arrangement for Farmers' Lines.—A somewhat different arrangement suitable for a **farmers' party line** that is used mostly by those on the same circuit is shown in Fig. 15. When the farmers wish to call each

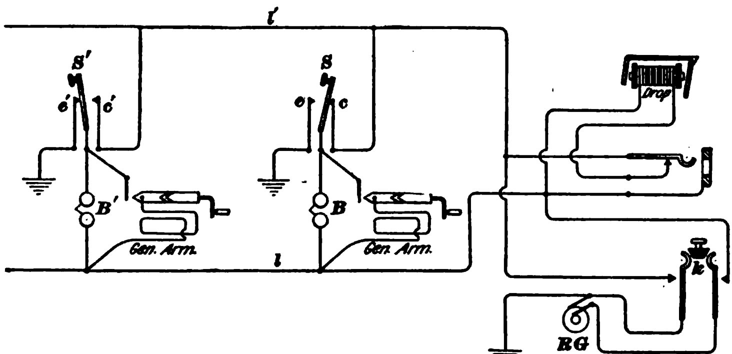


FIG. 15

other, they ring over line l and the ground, their switches, or push buttons, S, S' normally resting on contacts e, e'. By the proper ring, any station can thus be called. When one party wishes to call the exchange, he turns the switch S to contact c, which connects the instrument through a complete metallic circuit with the switchboard drop. Ordinarily, the exchange operator rings over line l and the ground by closing the ringing key k, but should any switch be carelessly left on contact c the ringing current from that station will return through line l' instead of through the ground. Hence all the bells will ring, no matter how the switches are left. This arrangement allows the exchange to be called secretly and, furthermore, the metallic circuit may be in use while two other parties are using line l and the ground as another circuit. The instruments may be arranged to use both line wires as a complete metallic circuit while any two parties are conversing, the ground merely being used as part of the signaling circuit.

DIVIDED-CIRCUIT TELEPHONES

31. A **divided party-line circuit** means one in which the operator is able to ring the parties whose bells are connected with one side of the line without disturbing those connected with the other side. The circuits are usually arranged so that when a subscriber is signaling the exchange, the bells of the other telephones on the same circuit are not disturbed. Such a two-party selective-signaling system is very desirable on toll and party lines.

32. The Dean Electric Company provides its divided-circuit telephones with biased bells connected to the ground binding post so that only one-half the bells will ring when the operator calls and none will ring when a subscriber's alternating-current generator is operated across the two line wires. Fig. 16 shows the way to connect these telephones to a line and to the ground.

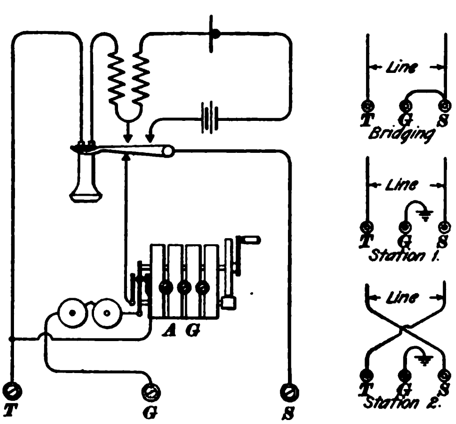


FIG. 16

Normally, the alternating-current generator *A G* is short-circuited, the line *S* is open at one generator spring, and the bell is connected from line *T* through a pair of generator springs to the ground post *G*. When the generator handle is turned, its armature is connected across the line posts *T*, *S*; the bell having one terminal connected to the ground post *G*, is not then in the circuit. Two-party selective ringing is obtained by connecting one bell between each side of the line and the ground, the ordinary alternating ringing current being used. This arrangement is extensively used in large city exchanges.

For divided-circuit service, any reasonable number of telephones can be bridged across the line, one-half connected as for station *1* and the remainder for station *2*, thereby causing only one-half of the subscribers to be rung when the operator signals. The way to connect the binding posts for one telephone bridged across the two line wires, or for one signaling circuit between each line wire and the ground, is shown in the right-hand part of this figure.

33. Divided-Circuit Central-Checking Telephones. Several companies make what are termed **divided-circuit central-checking telephones.** The telephone instrument is equipped with either a 1,000-, 1,600-, or 2,000-ohm ringer and a four- or five-bar generator arranged to give a pulsating direct current that will not ring the ordinary polarized bells, but will operate a switchboard drop. The generator is connected across the two line wires, so as to ring through the metallic circuit, while half the bells are connected between one side of the line and the ground and the other half of the bells are connected between the other side of the line and the ground. Turning the generator will operate only the switchboard drop. The ringing keys at the switchboard are arranged so that the operator can connect the exchange generator between either side of the line and the ground, or across the two sides of the circuit, in order to ring an ordinary bridging bell (private-line telephone) connected directly across the line circuit. In such an arrangement, the subscribers can only call the exchange operator.

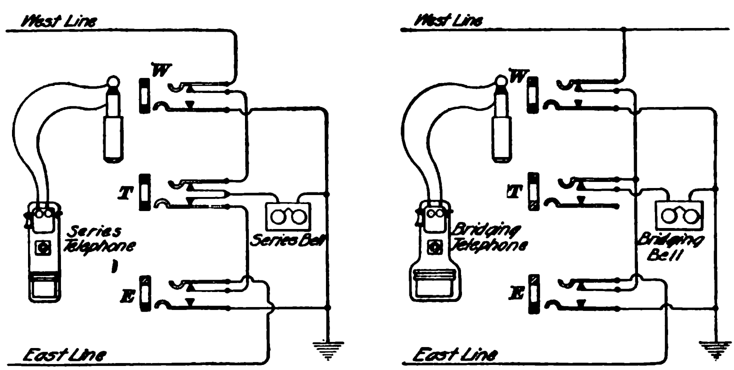
By using two bells biased for currents flowing in opposite directions between each side of the line and ground and providing the operator with proper keys and currents, a four-party selective-ringing system is obtained.

34. Condensers in Telephone Circuits.—For two-party service in central-energy systems, a condenser is usually connected between each bell and the ground. Where a condenser is used to ring and also to talk through, a 2-microfarad condenser is about the best to use. With a standard four-bar magneto-generator, an 80-ohm bell can be

rung through a 2-microfarad condenser by properly adjusting the bell; although the bell may be rung more easily through a 4-microfarad condenser, the latter is hardly necessary. By having a central-office generator giving as high as 100 volts on open circuit, first-class 80-ohm bells connected in series with 2-microfarad condensers can be rung without any difficulty whatever.

SUBDIVIDING A PARTY-LINE SYSTEM

35. By Means of Jacks and Plugs.—On long, rural, party-line systems, it often occurs that while a subscriber is talking over the line in one direction, for instance, east, some one on the west end would like to make a call on that unoccupied part of the line. The arrangements shown in Figs. 17 and 18 for accomplishing this purpose with ordinary



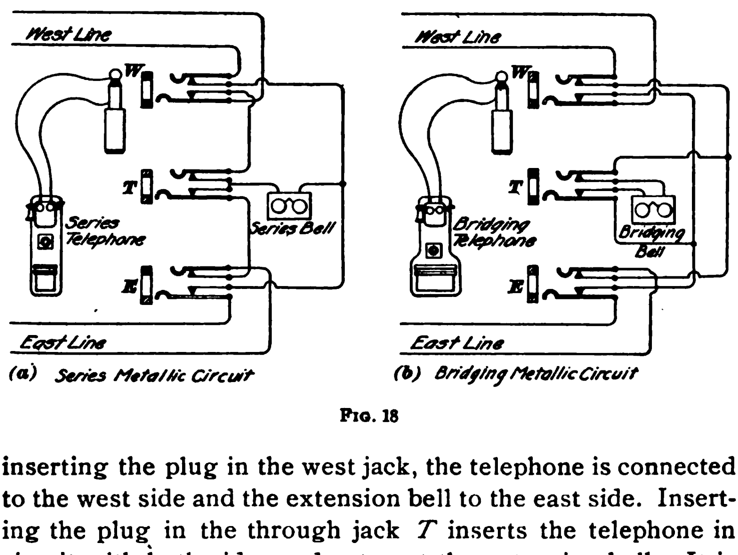
(a) Series Grounded Circuit (b) Bridging Grounded Circuit

FIG. 17

jacks and plugs are generally much better and cheaper than those having strap or knife switches, which have been used to some extent. Three spring jacks may be mounted in a magneto-bell box; for the purpose of explanation, they are here designated by the letters *E*, *T*, and *W*, which stand for east, through, and west, respectively. The terminals of the telephone at each station where the three jacks are used are

connected to an ordinary two-wire plug. Fig. 17 (*a*) shows the connection of the three jacks and one extension bell for a series-grounded party-line system; Fig. 17 (*b*), for a bridging grounded system; Fig. 18 (*a*), for a series-metallic-circuit system; and Fig. 18 (*b*), for a bridging metallic-circuit system.

By inserting the plug in the east jack, the telephone is connected to the eastern part of the line and the extension bell is left connected with the western part of the line, which is now divided into two parts. Any one wishing to use the western end may do so without interference; or should they wish to call the station where the plug is inserted in a jack, they can do so by means of the extension bell. Similarly, by



(*a*) Series Metallic Circuit (*b*) Bridging Metallic Circuit

FIG. 18

inserting the plug in the west jack, the telephone is connected to the west side and the extension bell to the east side. Inserting the plug in the through jack *T* inserts the telephone in circuit with both sides and cuts out the extension bell. It is necessary to use for the series-line an extension bell of the same resistance as the series-telephone bells, and, similarly, for the bridging line, an extension bell of the same resistance as the bridging-telephone bells. With the series-circuits, it is necessary to leave the plug in jack *T* when not in jack *W* or *E*, otherwise the series-bell, being connected across the

circuit, will short-circuit the line. With the bridging circuits, it is not necessary to leave the telephone plug in any jack.

36. An arrangement for accomplishing the same purpose that has the series-bell in series with the line and does not require the plug to be left in the middle jack *T* is shown in Fig. 19. This circuit is better than that shown in Fig. 17 (*a*), but requires a more complicated jack. In place of the jacks shown in Fig. 18 (*b*), a double-acting switchboard key may be used, as shown in Fig. 20. The cut-in station telephone *I* is normally bridged across the circuit with the key handle in a central position, as shown in this figure; either half of the line can be left connected with the bridging bell only and the other half of the line with the telephone *I*, by throwing the key lever in the proper direction.

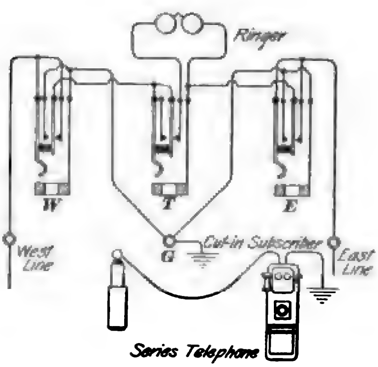


FIG. 19

37. The arrangements shown in Fig. 21 are said, by A. E. Dobbs, to be more desirable for bridging-telephone circuits, because there are fewer jack-contacts normally in circuit in the through condition of the line. The switches *S*, *S* should preferably be knife switches, which can be depended on to make good contact when closed. It will be seen that the jacks are bridged by the switches, which can be opened when testing for trouble in the east, west, or home circuit, or when it is desired to divide the line. With the switch open, the line

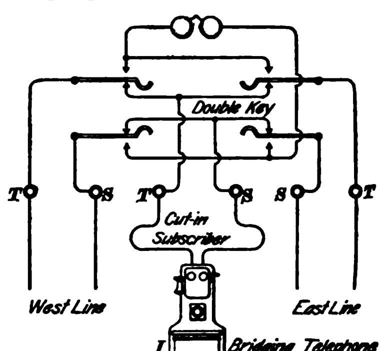


FIG. 20

is still closed through the jacks; and the insertion of the plug in one jack bridges the station telephone across one line and leaves the extension bell bridged across the other line.

38. A very simple device, given in the American Telephone Journal, that will accomplish very much the same

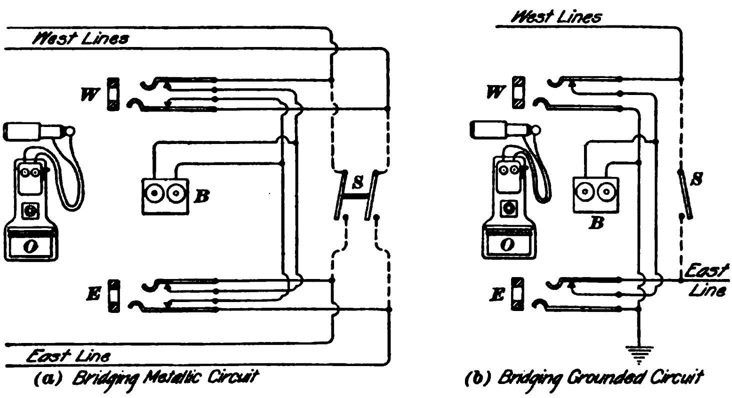


FIG. 21

result on a series-party line as the arrangements just described, is shown in Fig. 22, in which *a*, *b*, *c*, *d*, *e*, *f* are the line binding posts. A switch made of spring brass is so fastened to the center binding post of the series-telephone that it may be turned and held in contact with either line binding post, thus temporarily grounding either line binding post;

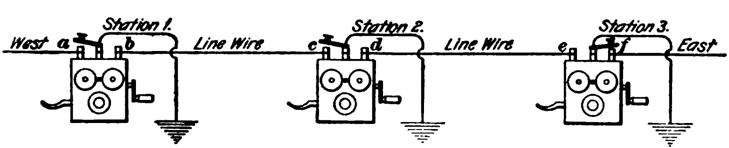


FIG. 22

but it must break this temporary contact when it is not held down by the fingers. Suppose that it is desired to ring to the west from station *2*. The switch at station *2* is held in contact with binding post *d*, while the generator crank is turned and may also be held down until the conversation is

finished. As the bells to the east are not now included in the western portion of the circuit, the bells to the west ring louder and the conversation is clearer than if the whole line were used; moreover, the east portion of the line can still be used by two subscribers on that side. Before using the line, the caller should listen in on the line and find out if it is in use; and if he is sure that no part or only the end of the line that he does not wish to use is being utilized, he can close his switch on the binding post on that side of his telephone, and keep it there until his conversation is finished; thus no one will be interrupted.

If the line happens to be open, the stations on either side of the break may still be called up by the stations on the same side of the break and, by means of the switch, a test can be quickly made to determine the direction in which a man should be sent to repair the break. It is very essential that the switch should spring away from the binding post when released; otherwise, there will be trouble continually from grounds on the line caused by careless subscribers leaving the switch on one binding post.

39. Residence and office service may be obtained by the arrangement shown in Fig. 21, omitting the switch *S* and the dotted lines. The west line may be considered as extending to the residence and the east line to the exchange. When the plug is inserted in jack *W*, the residence and office instruments are connected together, leaving only the bridging extension bell *B*, located in the office, connected across the exchange line. With the plug inserted in jack *E*, the bridging telephone *O*, located in the office, is connected to the exchange line, leaving only the office bell *B* across the residence line. With the plug removed, as shown in the figure, the residence telephone, which is supposed to be bridged across the west line, is connected straight through to the exchange with the office bell bridged across the circuit. The office bell enables the exchange to call up the office when the office telephone *O* is connected to the residence, or west, line and also enables the residence to call up the office when the office telephone

is connected to the exchange, or east, line. The plug, which is usually left in one of the jacks, is withdrawn only over night and during such other times as the office is closed.

40. Intermediate, or extension-bell, switches that have been much used for subdividing a grounded party-line circuit are shown in Fig. 23 (*a*) and (*b*). The switch shown in Fig. 23 (*a*) is intended for a series-grounded party-line

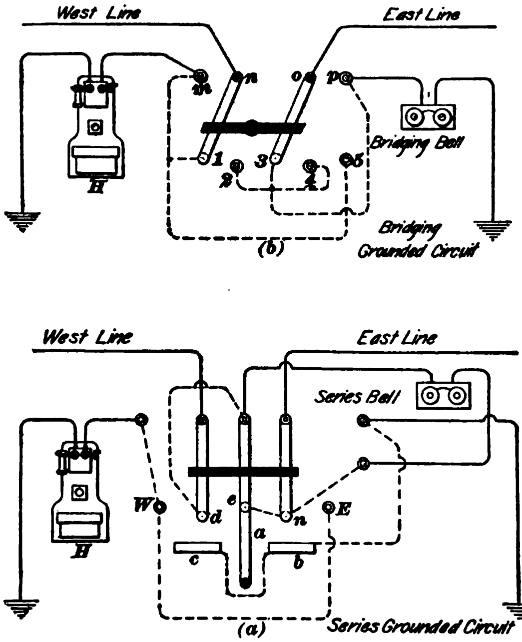


FIG. 23

circuit. It is so constructed that when it is turned to the left, the strap *a* touches the strip *c* but not the button *d*, the left-hand strap rests on *W*, and the right-hand strap on *e*. Similarly, when turned to the right, *a* touches *b* but not *n*, the left-hand strap rests on *e*, and the right-hand strap on *E*. In the middle position, as shown in the figure, *a* touches *e*. The switch shown in Fig. 23 (*b*) is intended for a bridging, grounded, party-line circuit. When the switches are turned

to the left, the telephone *H* is connected between the west line and the ground and the extension bell between the east line and the ground; when turned to the right, the positions of the telephones and extension bells are interchanged. With the series-switch in the intermediate position, the telephone is cut out and the extension bell is connected in series between the east and west lines. With the bridging switch, which is much simpler, in the middle position, the telephone *H* is cut out and the extension bell is bridged between the two line wires, which are now connected together, and the ground. When a call is received, it is usually necessary to turn the switch until connection is obtained with the side calling. The connections for both switches are so clearly indicated that no further explanation of either switch is necessary.

Where metallic circuits are used, the ground connections in (*a*) and (*b*) may be connected to the other line wire, which would then run through each station without being cut; the telephone instrument and extension bell would be connected to the through line wire instead of to the ground, as shown in this figure. Jacks and knife switches are much more reliable than these extension switches, because the contacts in the latter are apt to work loose and give trouble.

41. Residence and office service may be secured by the use of the extension switch shown in Fig. 23 (*b*). For instance, the east line could run to the exchange and the west line to the residence, the switch, telephone, and bell being located in the office. Exactly the same results are obtained by connecting contacts *1*, *2*, *4*, *5* to the ungrounded terminal of the office telephone and contact *3* to the bell. Where metallic circuits are used, instead of grounding the office telephone and extension bell, connect them to the second wire running to the exchange and residence.

42. Lock-Out Systems for Party Lines.—There are several objections to the ordinary party-line systems. The operator cannot ring one bell without ringing all the others, requiring a distinctive number of rings for each subscriber;

no means are provided for preventing one subscriber from listening to whatever conversation is going on over the line between two other subscribers; in other words, the service is not private; there is nothing to prevent one subscriber from interrupting the conversation of others by turning his magneto-generator; and there is the frequent report that the line is busy. The latter complaint may be reduced by the use of some form of measured service in place of unlimited service. These are somewhat grave defects, and lead to much trouble. They are not, however, serious enough to prevent the bridged party line, as described, from being used on many of the party-line systems in the United States.

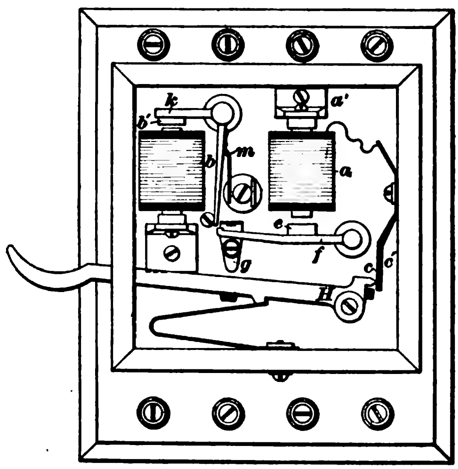


FIG. 24

43. Mechanism of Scribner System. Several kinds of lock-out systems have been devised with the idea of remedying these defects; one, the invention of Mr. Charles E. Scribner, is shown in diagram in Figs. 24 and 25. Before considering the circuits, the construction of the lock-out box, shown in Fig. 24, will be described. This box, which is ordinarily mounted on the same backboard as the telephone instruments, contains a hook switch H of the Warner type, having two contact springs c, c' (one behind the other), which make contact with the hook only when in its raised position. The arrangement is such that while the hook is rising, spring c will make contact with it slightly before spring c'. Within the box are two magnets a and b, of which a controls the continuity of the telephone circuits, and is therefore called the *circuit-controlling magnet*, and b controls a stop adapted to prevent the armature of a from being attracted,

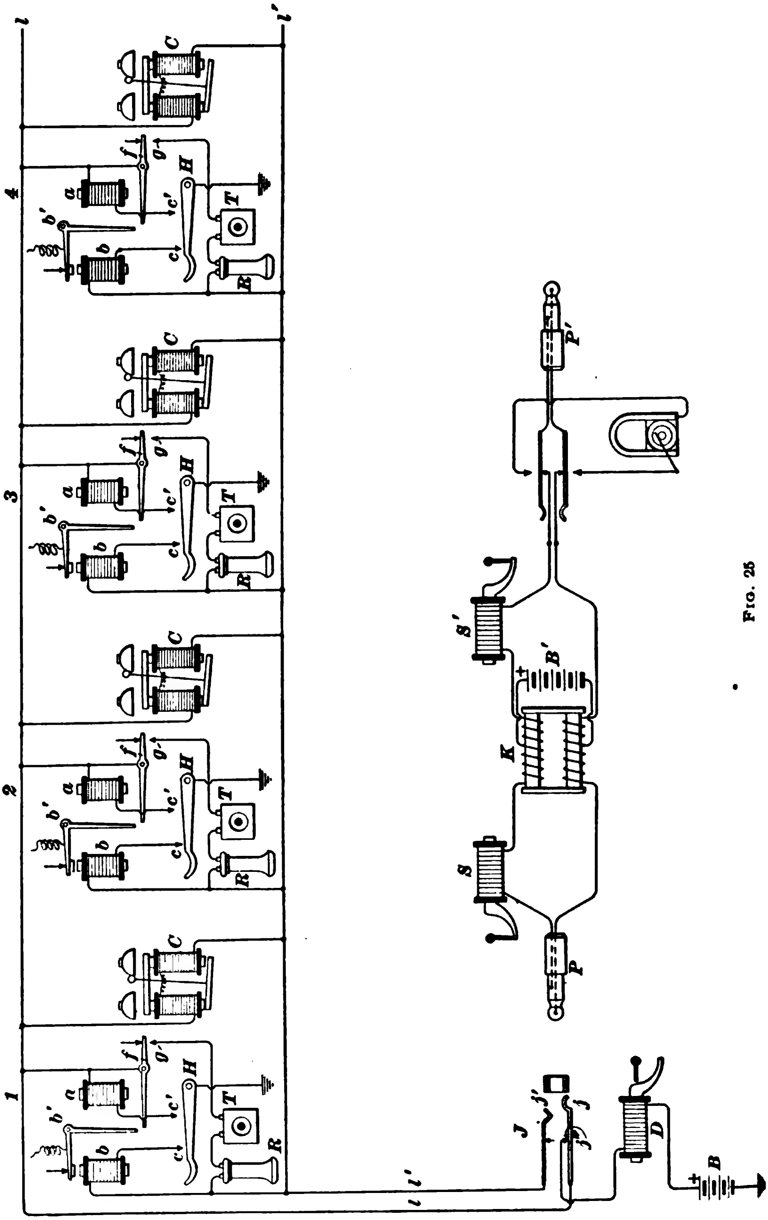


FIG. 25

and is therefore called the *stop-controlling magnet.* The magnet *a* is mounted in a vertical position on a bracket *a'* and acts on an armature *e* carried on a lever *f*, pivoted as shown. When the armature is attracted, the lever *f* engages a stationary contact *g* mounted on the backboard of the box, and the making of this contact, as will be seen later, closes the telephone circuit across the two sides of the line wire. One terminal of the winding of the magnet *a* is connected with the contact spring *c'* of the hook, while the other is connected with one side of the line wire. The magnet *b* is mounted alongside of the magnet *a*, and acts on an armature *b'* carried on the short arm *k* of a bell-crank lever. This armature is normally held away from the magnet pole by a spring *m* resting against an adjustment screw, as shown. When the magnet *b* is energized, it causes the lower end of the bell-crank lever to move to the right against the pressure of the spring *m*, until it lies directly in the upward path of the lever *f*. From this, it follows that if the magnet *b* is energized before the magnet *a*, the latter cannot cause its armature *f* to make contact with *g*. One terminal of the magnet *b* is connected to the contact spring *c* of the hook, while the other is connected to that side of the line with which the magnet *a* is not connected.

44. Circuits of Scribner System.—The operation of this system as a whole may be readily understood by reference to Fig. 25, which shows the circuits of four stations, *1*, *2*, *3*, and *4*, associated with the two sides *l*, *l'* of a metallic circuit connected with a spring jack *J* and drop *D* at central office. The mechanism at the subscribers' stations is shown in simplified form in order to better illustrate their connection in the circuits. The various letters used in connection with the lock-out mechanisms in Fig. 25 refer to the same parts as those used in Fig. 24. The circuit-controlling magnet *a* is connected between the line wire *l* and the contact *c'*; the stop-controlling magnet *b* is similarly connected between the line wire *l'* and the contact *c*. When the magnet *a* attracts its armature, the closure of the lever *f* against

the contact g completes the circuit containing the telephone receiver R and the transmitter T across the two sides of the line, as shown. The polarized call bell C at each station is permanently bridged across the line circuit, and is therefore made of high resistance and impedance to conform with the requirements of bridging-bell service.

At the central office is a spring jack J having springs j and j' connected, respectively, with the line wires l and l'. The spring j normally rests against an anvil j'' connected with one terminal of the drop D, the other terminal of which is grounded through the battery B. A pair of plugs P, P' are shown connected together by a cord circuit and split repeating coil K, according to the Hayes system of common-battery supply. The battery B' is connected between the center points of the windings of the repeating coil and furnishes current for talking, according to the methods already explained. S and S' are supervisory signals connected, respectively, in the sleeve strands of the answering and calling plugs.

45. Operation of Scribner System.—Assuming that subscriber *1* desires a connection with some other subscriber, he accordingly lifts his receiver from the hook; as the lever H rises, it makes contact first with c and immediately afterwards with c'. As no battery is connected with the line wire l', the closure of the contact c produces no effect on the magnet b and therefore the stop-controlling lever is not operated. The closure of the contact c' establishes a circuit from the battery B through the line wire l–magnet a–contact c'–lever H–ground–battery B. This causes the magnet a to close the contact point g, thus connecting the subscriber's telephone apparatus directly across the line. Should any other subscriber—for instance, *2*—now remove his receiver from the hook, the magnet b at his station will be energized, because the battery B is now connected with the line wire l' through the telephone apparatus at station *1*. This circuit may be traced from the positive pole of the battery B, through line wire l–station *1*–talking apparatus at that station–line

wire l'–station *2*–magnet b–contact point c–hook H–ground to the negative pole of the battery B. The action of magnet b, which occurs slightly before the magnet a at station *2*, causes the stop-controlling lever b' to move in the path of the lever f, thus preventing its closing the telephone circuit at station *2* through the contact point g. A little consideration will show that the first party to remove his receiver from its hook thereby secures the entire control of the line until he has finished his conversation, this being brought about by the connection of the battery with the line l', thus always assuring the operation of the stop-controlling magnet b at any other station when a second subscriber removes his receiver from its hook. When the operator plugs in, the battery B is cut off at the contact point j'', but the battery B' is bridged across the circuit in its place. This battery B' supplies current to the talking apparatus in a manner already described, and also serves, as explained in the following article, to maintain the same condition with regard to the lock-out mechanism as did the battery B.

46. The circuit by which the stop-controlling magnet b is operated at any station after the plug P is inserted is a little difficult to grasp, but assuming, as before, that subscriber *1* is using the line and that subscriber *2* removes his receiver, the circuit may be traced as follows: From the positive pole of battery B' through the sleeve strand of the plug P–sleeve spring j of jack–line wire l–magnet a at station *1*–contact point c'–hook lever and ground at station *1* –ground and hook lever H at station *2* (assuming that the party at that station tries to listen in)–contact c–magnet b–line wire l'–tip spring j' of the jack–tip contact and tip strand of the cord–negative terminal of battery B'. This circuit includes the stop-controlling magnet b at station *2*, causing that magnet to attract its armature, and thus prevent the operation of the armature lever f of the magnet a, with the result of locking out the subscriber. When the subscriber at station *1* finishes his conversation, he replaces his receiver on its hook; this breaks the connection that exists between

the two sides l, l' of the line and therefore stops the flow of current from the battery B' and allows the shutter of the supervisory signal S, which has previously been held in a horizontal position by the magnetic force of its core, to fall into the vertical position in which it is shown in Fig. 25.

47. If subscriber *1* desires to talk with subscriber *4* on the same circuit, the operator will request subscriber *1* to hang up his receiver and to take it down again when his bell is giving his particular ring. The operator will then proceed to withdraw the answering plug, insert in its place the calling plug, and then close the ringing key, giving the proper signal to call subscriber *4*. After subscriber *4* takes down his receiver, the operator will give the proper signal for subscriber *1*, who, according to previous instruction, will take down his receiver while his bell is ringing. The talking circuits of subscribers *1* and *4* will then be connected across the line wires, because the talking circuit of subscriber *4* was already connected across the two line wires, and the talking circuit of subscriber *1* can be connected across the line wires also, provided that he takes down his receiver while his bell is ringing, during which time there is no battery connected to the line circuit. When the ringing key is released so that battery current can flow from the line circuits, the magnets *a, a* at stations *1* and *4* will act quickly enough to prevent magnets *b, b* from locking out either station.

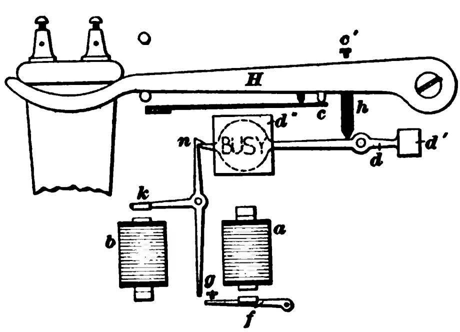


FIG. 26

48. Busy Signal of Scribner System.—As an improvement on the mechanism shown in Fig. 24, that illustrated in Fig. 26 has been devised by Mr. Scribner. In this figure, the various parts have the same reference letters as the

corresponding parts in Figs. 24 and 25, and are connected in the circuits in the same way. The bell crank lever *k* of the lock-out magnet *b* carries on its upper end a hook or catch *n*, adapted to engage and hold down the long end of a lever *d* carrying a weight d' on its short arm and a target or signal d'' on its long arm. The target d'' is normally held down by the catch *n*, being forced into that position by the insulating lug *h* carried on the hook switch. When, however, any subscriber tries to use the line when it is already busy, the magnet *b* will attract its armature, thus locking out that station in a manner already described, and at the same time releasing the lever *d*. When this lever is so released, the weight d' will cause the signal d'' to rise until it comes in front of an opening in the box, thus displaying the word "busy" to the subscriber. The subscriber therefore hangs up his receiver, thus causing the lug *h* to push the lever *d* into its normal position. This system, by preventing a second subscriber from cutting in on his line when it is already in use, overcomes only one of the objections to party lines. The other fault, i. e., the ringing of all the bells on a party line, when the operator wants to call up only one station, is overcome by what is termed selective signaling.

PARTY-LINE SYSTEMS

(PART 2)

SELECTIVE-SIGNALING PARTY LINES

1. Selective-signaling systems for party lines embrace all those systems in which means are provided for ringing the bell of any one subscriber on a line without ringing the bell of any other subscriber on the same line. They may be divided into three classes, as follows: first, those employing step-by-step mechanisms operated by impulses of current from the central station in such a manner as to close the calling circuits at the subscribers' stations successively; second, those using the harmonic, or reed, system of selecting, wherein currents of various frequencies are employed for actuating the different signals; and third, those using current of different strengths or of different polarities, or combinations of both, for operating the various signals.

STEP-BY-STEP SIGNALING

2. The general plan used in **step-by-step systems** is that of employing a mechanism at each of the various stations on the line that will close a circuit at its station after a certain predetermined number of current impulses have been sent over the line. The mechanism usually consists of an electromagnet operating a pivoted armature, which causes a pawl to move a ratchet wheel one notch for every attraction of the armature. Carried on the ratchet wheel, or connected with it by suitable gearing, is a contact arm so arranged as to engage a stationary contact at a

certain definite point in its movement. This contact point is differently located on each instrument, so that, when all the instruments are operated in synchronism, the circuits at the subscribers' stations will be closed one at a time. The arrangement on the line may be such that the contact lever of instrument *1* will engage its button after it has moved one step, that at *2* will engage its button after it has moved two steps, that at *3*, after three steps, and so on. In order to call any particular station—for instance *10*—the operator will send ten current impulses over the line, which will bring the contact lever at station *10* into engagement with its button. Those levers at the stations having smaller numbers will have passed over their buttons, while those at stations having larger numbers will not yet have reached their buttons. After the completion of the circuit at the desired station, the operator sends the ringing current over the line, which flows through the circuit completed at that station and sounds the bell of that subscriber only.

3. Faults of Step-by-Step Systems.—The step-by-step method of selective signaling appears to be a very promising one, but it has been difficult to secure proper electrical contacts between the stationary and movable contact points. Besides, the mechanism is rather complicated—an undesirable feature, especially when in the hands of inexperienced parties. But, owing to a demand for these systems, there are several, including the Nicholas, Meinema, Baird, and Stromberg-Carlson, on the market; as these, however, are constantly being improved and are difficult to understand without being seen, no descriptions of them will be given.

HARMONIC SIGNALING

4. Every vibrating pendulum or reed has a natural period of vibration out of which it is a comparatively difficult matter to make it vibrate with any great amplitude. This fact is made use of in the **harmonic selective systems** by placing a reed or pendulum at each subscriber's station, adapted in

each case to be acted on by a magnet in the line wire. The reeds at all the stations are tuned to vibrate at different rates; and when any one is thrown into vibration of the desired amplitude it causes the bell to ring. At the central office, transmitting devices or keys are provided, each adapted to send over the line circuit rapidly pulsating or alternating currents, the frequencies of which correspond to that of the reed at one of the substations. Thus, in order to call any particular station on a line, the operator, by means of one of the transmitting keys, sends a pulsating or alternating current of the proper frequency to line; the frequency of the impulses of this current, being the same as the natural rate of vibration of the reed at the station that it is desired to call, will throw that reed into motion. As none of the other reeds at the other stations have a rate of vibration corresponding to that of the particular current used, their reeds will not be thrown into vibration, or at least not with sufficient amplitude to cause their bells to ring.

5. Faults of Harmonic System.—Up to 1902, no harmonic method of signaling had proved sufficiently successful to be continued in use, and but one or two such systems had been in operation in the United States. One reason for this was that it was very difficult to secure a good contact between a rapidly vibrating reed and a stationary contact, which was necessary in the old harmonic systems. Another reason was that the adjustment of the rates of vibration of the various stations was apt to be so delicate as to be changed by variations in temperature or by other unavoidable causes. About 1902, W. W. Dean developed a system for the Kellogg Switchboard and Supply Company that has proved successful. This system is fully explained in connection with the Kellogg central-energy system. Practically the same system is also being made by the Dean Electric Company. The first difficulty mentioned is entirely eliminated by not having any make-and-break device in the subscriber's telephone, while the second seems to have been eliminated by good design and construction of the apparatus. For successful operation,

the various frequencies used must be maintained very constant, for which purpose it is usually necessary to equip the ringing generators with governing devices. It is usually necessary, but not always easy, to maintain the proper adjustment of the bells and other signaling devices.

DEAN PARTY-LINE SYSTEM

6. W. W. Dean has developed, for the Dean Electric Company, a successful harmonic selective-ringing party-line telephone system. The ringer is shown in Fig. 1 (*a*) and several detailed parts in (*b*) and (*c*). Practically, the only difference between this and a regular Dean ringer is that the armature is spring-mounted instead of pivoted and the cylindrical hammers *h* and springs *i* are made in different sizes for the four differently pitched bells. The proper position of a gong may be very accurately secured by means of a worm-screw *d* that engages teeth in the piece *c* that is pivoted at *e*, the gong being mounted on a stud riveted in the piece *c*. The bell is self-contained and may be mounted in place of any ordinary bridging bell.

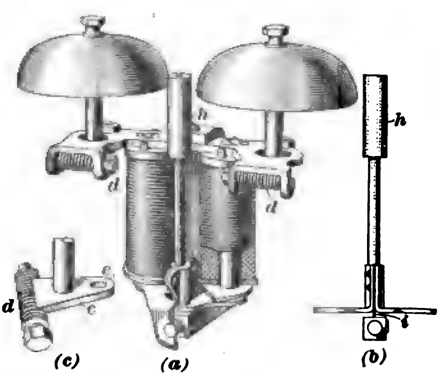


Fig. 1

The armature and tapper rod normally stand in the central position with reference to the pole pieces and gongs. When a current of proper frequency passes through the line, the hammer will be thrown into vibration and the ends of the armature brought against the pole pieces where it comes to a sudden stop, requiring the tapper to spring about $\frac{1}{32}$ inch, in order to hit the gongs when they are properly adjusted.

7. The four generators that produce the ringing currents of four frequencies are designed to give about the same maximum voltage, which is not the voltage measured by an ordinary commercial voltmeter. The tappers are adjusted at the factory to be in tune with the ringing currents.

The **harmonic converter** made by the Dean Electric Company resembles four separate pole changers mounted on top of a cabinet in which 72 dry cells may be placed. The converter may be operated from any source of direct current, such as primary batteries, storage batteries, or from the power plant of a central-energy exchange. It is said to require very little current to operate it, and that it produces a strictly alternating current approaching that of a true sine wave, thereby causing less inductive disturbance than the sharp waves produced by the ordinary pole changer. The four frequencies produced are $16\frac{2}{3}$, $33\frac{1}{3}$, 50, and $66\frac{2}{3}$ cycles per second. The output may be made sufficient for an exchange of any size. To run a converter for a 6,400-line exchange when no ringing current is being used, requires about $6\frac{3}{4}$ watts, or .28 ampere at 24 volts, and about twice this amount when ringing on a bridged four-party line of zero resistance. Where primary batteries must be used, the harmonic converter is provided with a master circuit-closing relay, so that the only current consumed by the converter is that used in keeping the vibrating mechanism in motion, less than .58 watt being required.

Four bells of different frequency are connected across a pair of line wires and any one of the four may be rung by connecting a source of alternating current of proper frequency across the two line wires at the exchange. On rural lines, which are usually free from inductive disturbances, the bells and condensers of four telephones may be connected between each side of a line and the ground, giving an eight-party selective-ringing system. No further explanation of this system is necessary, as it differs in no material respect from the Kellogg system.

LEICH PARTY-LINE SYSTEM

8. A system that depends on the use of currents of different frequencies, but can hardly be called a harmonic system, is the one devised by Mr. Leich and made by the American Electric Telephone Company. For selective ringing, this system uses alternating currents of two frequencies, one of twenty cycles per second and one of sixty cycles per second. By applying currents of these two frequencies between one or the other side of a metallic circuit and the ground, it is possible to ring any one of four bells, two of which are connected in suitable circuits between each side of the line and the ground.

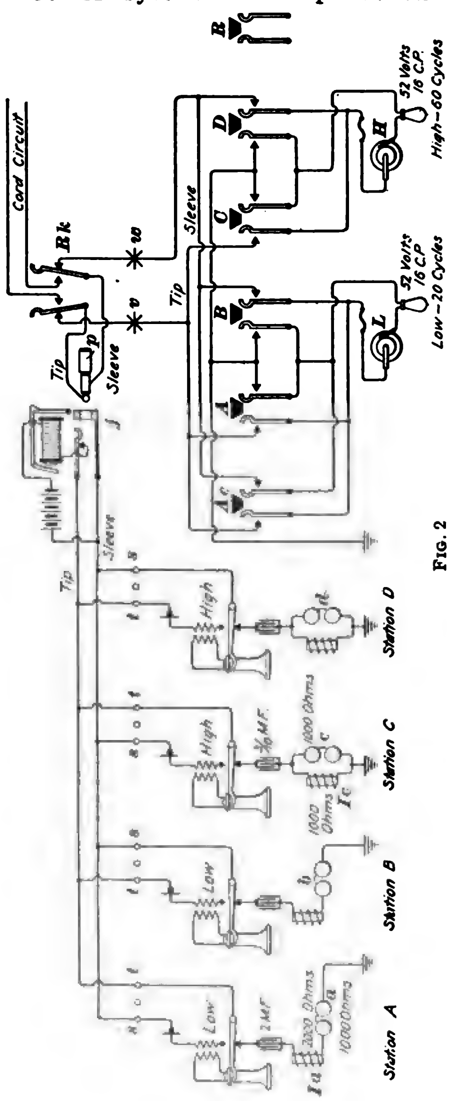


FIG. 2

9. The connections of the **Leich four-party selective system**, arranged for use on a central-energy exchange circuit, are shown in Fig. 2. At the two

stations *A*, *B*, whose bells are rung by the low-frequency current, a 2-microfarad condenser, a 2,000-ohm impedance coil, and a 1,000-ohm polarized bell are connected in series; at station *A*, this combination is connected between the tip side *t* of the line and the ground; and at the other station *B*, the same combination is connected between the sleeve side *s* of the line and the ground. At the two stations *C*, *D*, whose bells are rung by the high-frequency current, a 1,000-ohm impedance coil is connected in parallel with a 1,000-ohm bell and this joint circuit is in series with a $\frac{3}{10}$-microfarad condenser. At station *C*, this combination is connected between the tip side *t* of the line and the ground; and at the other station *D*, the same combination is connected between the sleeve side *s* of the line and the ground. For talking purposes, the line is used metallic.

A selective-ringing key having the requisite number of buttons is provided at the switchboard. In the figure, *R k* represents the regular ringing key in each cord circuit; all these keys at one operator's position are joined at *v*, *w* to the row of keys *R*, *D*, *C*, *B*, *A*, *A c*, which constitute a master key, one such key being provided at each operator's position. Where enough party lines are used to warrant a more complete equipment, each cord circuit may be provided with a selective key having four buttons in addition to the usual double-throw listening and ringing key.

10. Operation.—The depression of key *A* connects the low-frequency generator between the tip side of the line and the ground, thereby ringing the bell at station *A* only. At station *A*, the capacity of the condenser and the inductance of the impedance coil and bell may be so proportioned that they about neutralize each other for a frequency of twenty cycles, the impedance of this circuit then being little or no greater than its resistance; at any rate, the total impedance is low enough to allow sufficient current to readily pass through and ring the bell.

The bell at station *C* does not ring, because the capacity of the condenser and the combined inductance of the coil and

bell are not proportioned to neutralize each other at a frequency of twenty cycles; at any rate, their combined impedance is not low enough, and the impedance of the coil is too low compared with the impedance of the bell to allow enough current to flow through the bell to ring it at the lower frequency. The bells at stations *B* and *D* have no tendency to ring, because no current is applied to the sleeve side of the line to which they are connected. The same conditions prevail when key *B* is depressed, except that the low-frequency current is now applied to the sleeve side of the line and hence only the bell at station *B* rings.

11. When the key *C* is depressed, the high-frequency generator *H* is connected between the tip side of the line and the ground, thereby ringing the bell at station *C*. At station *C*, the capacity of the condenser and the inductance of the circuit may be so proportioned that they about neutralize each other at a frequency of sixty cycles. Moreover, whatever current does pass through the $\frac{3}{10}$-microfarad condenser must divide through the two parallel paths, but the inductance of the impedance coil is high enough, relative to that of the bell, to make its impedance at sixty cycles sufficiently great to force enough of this current through the bell to ring it. If the inductance of the impedance coil is greater than the inductance of the bell, the smaller will be the proportion of the current that is forced through the bell as the frequency decreases. Hence, at a frequency of twenty cycles, only a small portion of whatever current may pass through the $\frac{3}{10}$-microfarad condenser can pass through the bell, consequently the bell does not get enough current at the lower frequency to ring it. The result of the arrangement at station *C* is to allow enough of the high-frequency current, but not enough of the low-frequency current, to pass through the bell to ring it. The bell at station *A* does not ring, because at a higher frequency the capacity and inductance at that station no longer neutralize each other, and at sixty cycles the impedance of this circuit is so great that the bell *a* does not get sufficient current to ring it.

The same conditions prevail when key *D* is depressed, except that the high-frequency current is now applied between the sleeve side and the ground and hence rings only bell *d*.

12. If ringing current of either frequency is sent over either line wire to ground, that current is sent through the ringing circuits of two instruments, namely, a high and a low instrument; but, on account of the construction of these ringing circuits, only one bell will respond, either the high or the low, depending on whether high- or low-frequency current was impressed on this line wire. The same is true of the two instruments having their ringing circuits connected to the other line wire on the same circuit.

13. The connections of telephone instruments for selective signaling by the Leich method on ordinary magneto-switchboard systems are shown in Fig. 3. The arrangement

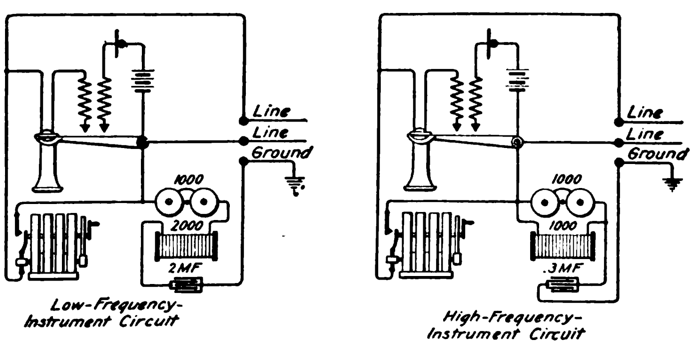


Fig. 3

of the bell, condenser, and impedance coil is the same as in the central-energy instruments. In both magneto- and central-energy instruments, a complete metallic circuit is used while talking.

In order to be able to ring single-line subscribers, it is necessary, when the master key is employed, to depress the button marked *Ac*, as well as the regular ringing key *Rk*. The buttons of the master key are all self-locking, that is, they remain in a depressed condition when actuated, until

another button is depressed, when the previously depressed button is automatically released. The button *R*, when depressed, mechanically releases any of the other buttons that may have been depressed.

14. For a metallic, two-party, selective system, a low- and a high-frequency instrument are connected across the two line wires, no ground connection being required; in this case, the low-frequency station and ringing key are designated by the letters *A C* and the high-frequency station and key by the letters *B M*. This requires only a three-button selective key connected as indicated in Fig. 4 (*a*). On grounded or common-return systems, it is only possible to operate a two-party selective system.

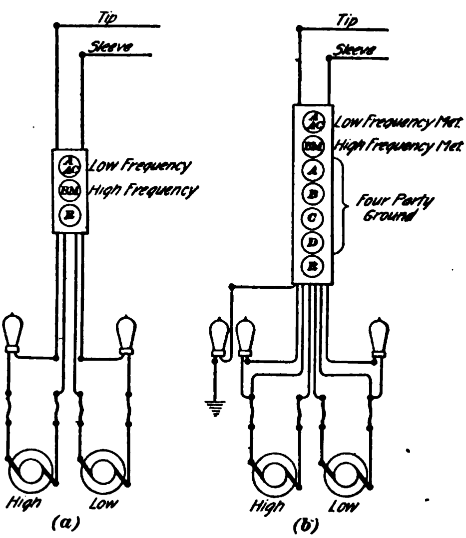


Fig. 4

Where four-party ground, two-party metallic, and single metallic services are given, the selective key shown in Fig. 4 (*b*) is required. This key should not be understood to mean that these three services, or even any two of them, can be given over one metallic circuit, but rather that some lines at any operator's position may be equipped with two-party metallic, some with four-party grounded, and others with only one ordinary telephone across a pair of wires. The keys *A*, *B*, *C*, *D* would be used for selective ringing on the four-party grounded lines, the keys *A C* and *B M* for selective ringing on the two-party metallic lines, and the key *A C* for ringing on private lines. At the exchange, the line drop or other line signal must be

arranged so as to be cut out when the plug is inserted in the jack.

15. The impedance coil is constructed as shown in Fig. 5. The laminated core *c* consists of **E**-shaped annealed-iron punchings *b* that can be inserted and withdrawn from either end of the coil, if for any reason it is necessary to change its inductance. Adding more iron punchings increases the impedance of the coil; and withdrawing the punchings reduces the impedance. By removing iron from the impedance coil of the low-frequency instrument, more current is permitted to go through the ringer coils; while a removal of

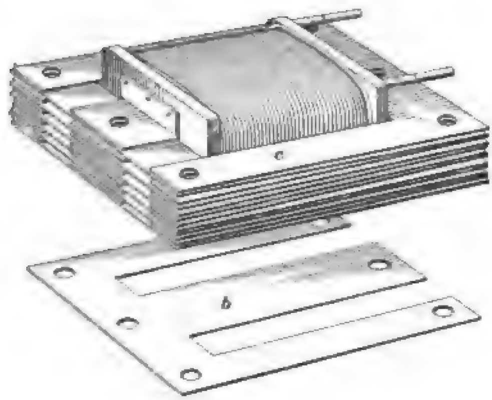


FIG. 5

iron from the impedance coil of the high-frequency instrument reduces the flow of the current in the high-frequency ringer coils.

16. The twenty- and sixty-cycle ringing currents may be produced by two similar armatures mounted on the same shaft and revolving at a speed of 1,200 revolutions per minute, the armature producing the low-frequency current revolving in a two-pole field; and the one producing the high-frequency current revolving in a six-pole field. The alternations of the low-frequency current should not vary more than 5 per cent. and the voltage not more than 10 per cent. above or below 104 volts. The frequency of the current, when supplied by a machine driven by a belt or other

flexible coupling, is generally unreliable; therefore, it is preferable to use a motor coupled directly to the shaft of the generator. A satisfactory low-frequency pole changer or a hand generator, when not turned too fast, may be used to give the low-frequency current.

The American Electric Telephone Company makes a hand generator so constructed that it cannot be turned too fast. A small power magneto, when running at a speed not to exceed 1,200 revolutions per minute, may be used.

17. The high-frequency, alternating, ringing current may be obtained from a regular ringing machine delivering a sixty-cycle current, or from a power magneto driven at the right speed, but care should be taken in this case not to get the voltage too high.

The Warner high- and low-frequency pole changer may be used to supply both frequencies, although a motor generator is preferable. High-frequency pole changers are not very satisfactory for ringing the high-frequency bells.

In cities having a sixty-cycle, alternating-current, incandescent-light system, high-frequency current may be obtained through a transformer without the use of any motor generator. This is more satisfactory than a pole changer for ringing the high-frequency bells.

18. Advantages and Disadvantages.—As there is a condenser in each ringing circuit, there is no metallic ground on either side of the line, hence there is no leakage of battery current when this party-line system is used on a central-energy system. In case any receiver is left off the hook or removed while the operator is ringing, the two bells of similar frequency, one on each side of the circuit, will ring because sufficient current will usually pass through the removed receiver in local-battery instruments, or through the transmitter in central-energy instruments, to ring the bell on the wrong side. It is, moreover, sometimes difficult to keep the bells adjusted so that they will ring properly, due to variation in frequency or voltage of the ringing machines and to improper adjustment of the bells. These bells may be made

similar to the ordinary polarized bells; however, the later ones are usually provided with two permanent magnets instead of one—one end of one magnet being placed over one end of the armature and directly opposite the end of one core, and one end of the other magnet over the other end of the armature and directly opposite the end of the other core. This causes the armature to be more intensely polarized.

19. Installation and Adjustment of Telephone Instruments.—When the instruments are installed, it is necessary to have the gongs on the instrument in such position that the bell hammer does not touch either when it is resting in its normal state on either side. The gongs will thus be struck by the hammer when it is operating, due to the elasticity of the arm. This precaution should be taken with all telephone ringers, whether selective or not. It is further necessary that the armature of the ringer should touch the pole pieces when in its normal position on either side. It is also of importance that the ringer armature be securely pivoted in its bearings without any lost motion, so that the armature cannot move up and down bodily, but will be confined to an oscillatory motion. The armature of the high-frequency bell must be adjusted to have less play, or movement, than that of the low-frequency bell.

In case there is any difficulty experienced in operating the telephones on some types of central-energy circuits, the first thing that should be done is to take a voltmeter reading at the instrument when the ringing current is on the line, and if found too low, the switchboard circuit may be modified or the ringing-generator capacity increased so that the ringing current is ample. A good ground is always necessary. In case the switchboard circuit or ringing generator cannot be changed, a change of iron in the impedance coils will serve to change the characteristics of the instruments so as to adapt them to entirely different conditions. The instruments operate through quite a range of action without any alteration of the iron in the impedance coil.

POLARITY SYSTEMS

20. **Polarity systems** are those in which the signaling is accomplished by changes in the direction of the current flowing in the line. Although at first this general method seemed to present smaller possibilities than either the step-by-step or the harmonic method, it has come into wider use than either and is now operating with entire success in many exchanges. A biased bell or a relay with polarized armature and magnet cores can readily be made to respond to currents in one direction only; obviously, this, in itself, on a single line wire affords means for signaling either of two stations exclusively of the other, for one of the bells or relays may be polarized to respond only to currents in a positive direction and the other only to those in a negative direction. This idea, in combination with that of causing various magnets to operate in different manners when traversed by currents of different strengths, was used in many of the early attempts in this line of work and gave the name "strength and polarity" to the entire class of inventions. The successful systems, however, have depended almost entirely on the changes in direction or character of the current in the line, for it has been found unsatisfactory, in most cases, to rely on the strength of the current.

CLAUSEN EIGHT-PARTY-LINE SYSTEM

21. An eight-party-line system made by the American Electric Telephone Company is shown in Fig. 6. In each telephone, there is a polarized relay, which consists of a permanent magnet *m*, and a coil and soft-iron core *c* pivoted at the upper end. The lower end of the core has attached to it a soft-iron armature *a*. A current in a certain direction will cause the armature *a* to move toward the north pole *n* and so close the bell circuit; a current in the opposite direction will merely assist the spring *e* to keep the bell circuit open. To make the polarized relay act more slowly, the iron core is provided with a thick coating of copper. The

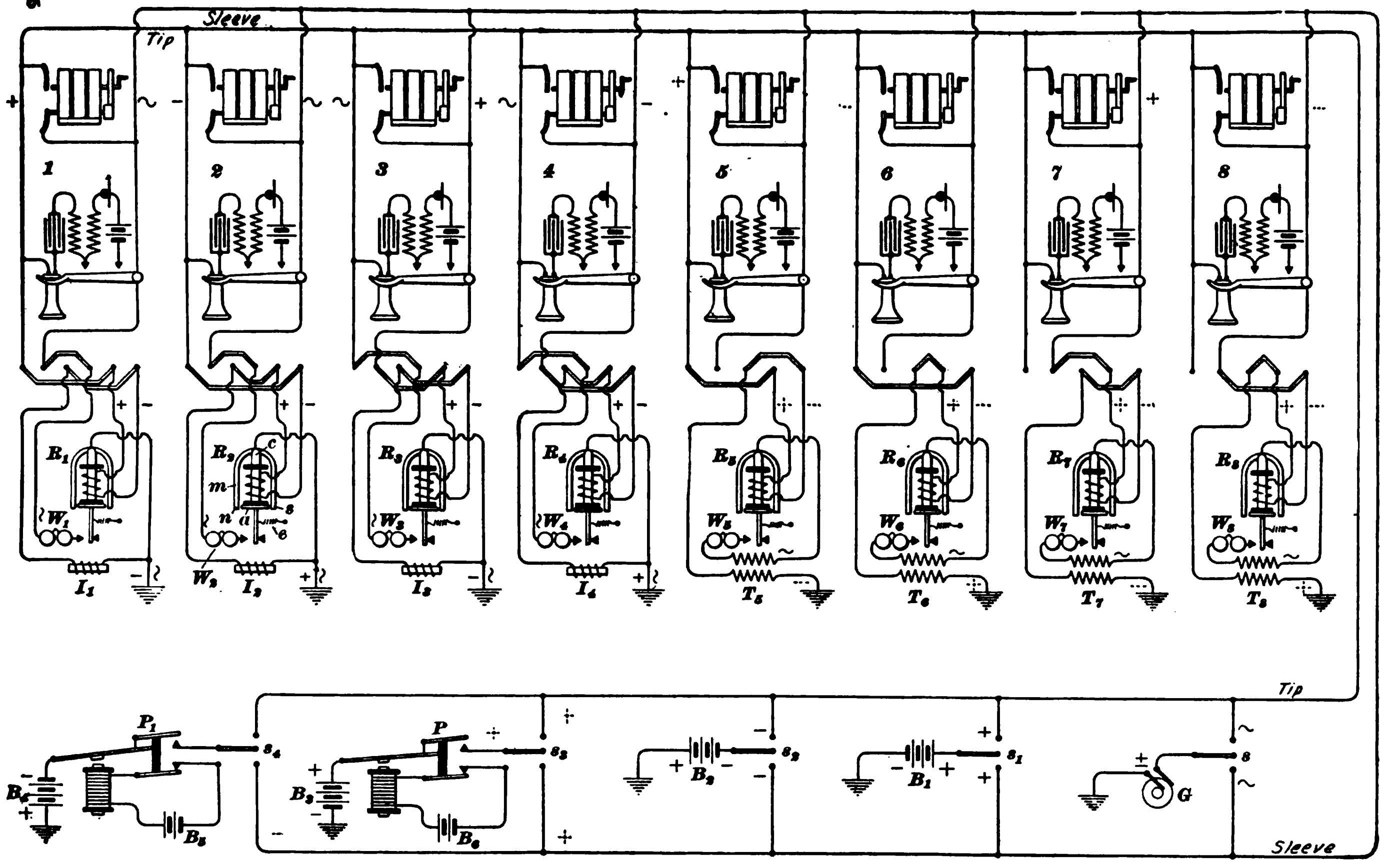

Sleeve
Tip
1
2
3
4
5
6
7
8
B_1
B_2
B_3
B_4
B_5
B_6
B_7
B_8
W_1
W_2
W_3
W_4
W_5
W_6
W_7
W_8
I_1
I_2
I_3
I_4
T_5
T_6
T_7
T_8
P_1
P
B_4
B_5
B_3
B_6
B_2
B_1
G
s_4
s_3
s_2
s_1
s

Fig. 6

relay will not respond until the current through it has reached its steady value. When the current through it from the line ceases, the decreasing current will induce a current in the copper coating that will prevent a rapid demagnetization of the core; therefore, the relay armature does not drop off after it has been drawn up when the current is merely interrupted at a rate of about twenty times per second. Four of the telephones are provided with impedance coils I_1, I_2, I_3, I_4, the cores of which may be more or less filled with thin iron plates, thus making the impedance adjustable, as explained in connection with the Leich party-line system. The telephones equipped with impedance coils are called *impedance stations*. The remaining four telephones are provided with repeating coils, or transformers, T_5, T_6, T_7, T_8, and are called *transformer stations*.

22. At the two impedance-coil stations *1*, *2*, the impedance coils and polarized relay windings are connected in series between the ground and the tip side of the line, but the relay windings are reversed in direction at the two stations, and the bells and relay contacts are in a circuit between the ground and the sleeve side of the line. At the two remaining impedance-coil stations *3*, *4*, the connections are the same, except that they are reversed with respect to the tip and sleeve sides of the line.

At the two transformer stations *5*, *6*, the relay windings and primary coils of the transformers are connected in series between the ground and the tip side of the line, but the relay windings are reversed in direction at the two stations, and the bells, secondary coils of the transformers, and the relay contacts form a separate local circuit at each station. At the two remaining transformer stations *7*, *8*, the connections are the same, except that the circuit containing the relay windings and primary transformer coils are connected to the sleeve, instead of the tip, side of the line.

23. The exchange is provided with an ordinary, alternating-current, ringing generator G (one terminal of which is grounded), two batteries of equal and suitable voltage B_1, B_2

(with opposite terminals grounded), and two interrupting devices P, P_1 that open and close about 20 times per second, the circuit containing the batteries B_3, B_4, the opposite terminals of which are grounded. As merely indicated by the switches s, s_1, s_2, s_3, and s_4, the ungrounded terminals of G, B_1, B_2, B_3, and B_4 may be connected to either side of the line.

24. Operation.—To ring only station *1*, connect the plus battery, that is B_1, to the tip side and the generator G to the sleeve side of the line; this will cause positive current to flow through the windings of relays R_1, R_2, but only R_1 will close its local circuit, because it flows through R_2 in the wrong direction, thereby allowing alternating current to flow through and ring only the bell at station *1*. The resistance of the impedance coils is low enough to allow the relays to receive all the direct current required to operate them.

The alternating current that can flow through the windings of relays R_3, R_4 is reduced so much in strength by the impedance coils I_3, I_4 that these relays are not affected. Relay R_5 may close its local circuit, but only direct current passes through the primary of the transformer, and, owing to the relay being somewhat sluggish in its action, the direct current becomes constant in strength before the relay armature is drawn up, hence no current is induced in the secondary winding and the bell does not ring. If the relay was quick acting, the bell would probably give at least a single tap. The relay R_6 will not be operated because the direct current through it is in the wrong direction. At stations *7* and *8*, there is no closed path for the direct current, and the relays will not be operated by the alternating current.

25. To ring only station *2*, connect the negative battery B_2 to the tip and the alternating generator to the sleeve. To ring only station *3*, connect the positive battery B_1 to the sleeve and the generator to the tip. And to ring only station *4*, connect the negative battery B_2 to the sleeve and the generator to the tip. To ring only station *5*, connect a positive pulsating current from B_3 to the tip side of the line. This will flow through R_5, and, being in the right direction, will cause it to

close its local circuit containing the bell and secondary winding of the transformer T_6. The pulsating current in the primary will induce an alternating current in the secondary, thereby ringing this bell. No other bell will ring. At station *1*, the relay will draw up its armature, but there is no current on the sleeve side of the line. At station *2*, the relay will not receive current in the right direction to operate it. There is no current on the sleeve side of the line, hence relays R_3, R_4 are not affected and the current on the tip is in the wrong direction to close the relay R_6. At stations *7* and *8*, the tip circuit is open.

To ring only station *6*, send an interrupted negative current from B_4 over the tip side of the line. To ring only station *7*, send an interrupted positive current from B_3 over the sleeve. And to ring only station *8*, send an interrupted negative current from B_4 over the sleeve side of the line. Alternating currents must flow through the ordinary polarized ringers W_1, W_2, etc. at each station in order to ring them.

Plus and minus signs indicate that positive and negative currents, respectively, must flow in the circuits so marked, in order to ring or assist in ringing the bell at that station. Similarly, dotted plus and minus signs indicate positive and negative interrupted currents, and the wavy sign (~) indicates an alternating current. Thus, at station *4*, a negative current must flow from the sleeve side of the line through the relay R_4 and impedance coil I_4 to ground, and an alternating current from the tip side of the line through the bell to the ground to ring the bell W_4; at station *7*, an interrupted positive current must flow from the sleeve side of the line through the relay R_7 and primary winding of the transformer T_7 to ground, thereby inducing an alternating current in the bell circuit in order to ring this bell W_7.

26. The operators are provided with sets of party-line ringing keys, each set having eight keys. The depression of any one key will make all the connections necessary to ring the station desired. The same battery may be used, in

practice, for both B_1 and B_2 and another battery for both B_3 and B_4. Either of these batteries, if of suitable voltage, may be used at B_5 and B_6 to operate the vibrating devices.

BIASED BELLS

27. Bells adapted to be rung by pulsating currents in one direction only are called **biased bells.** The impulse in one direction passing through such a bell pulls the armature against one pole, while during the interval of no current, which has the same length as the current impulse, a spring attached to one end of the armature pulls the latter back to its normal position. The only effect of a current impulse in the opposite direction will be to hold the armature more tightly in its normal position.

Biased bells may be connected to a complete metallic circuit in three ways: first, two bells, biased for current impulses in opposite directions, may be connected across the two line wires; second, two bells may be connected as just stated and two additional bells, also biased for current impulses in opposite directions, may be connected between either side of the line and the ground; and third, two bells, biased for current impulses in opposite directions, may be connected between each side of the line and the ground. The second arrangement cannot be modified by connecting two additional bells between the other side of the line and the ground because the current over either side of the line can then flow to ground, not only through the two bells between it and the ground, but also through the two bells connected across the line wires and then through the remaining two bells between the other side of the line and the ground, thus ringing three bells instead of one only, and, moreover, the current through each bell is considerably reduced in strength.

In the third arrangement, which is the one generally used, a positive pulsating current is sent out over either side of the line, returning through the two bells connected to that side of the line and the ground to the central office; one bell

is arranged to be rung by a positive pulsating current and the other by a negative pulsating current. The bells connected to the other side of the line are arranged and rung in a similar manner. Thus the operator, by being provided with suitable party-line keys and a source of positive and negative impulses, is enabled to ring any one of the four bells connected on such a party-line circuit by sending current impulses of the proper direction over the proper side of the line circuit. Such arrangement of biased bells, ringing keys, and generators for producing positive and negative impulses is frequently called the **Genesee party-line system.** It is practically the same as the Hibbard system, which will presently be illustrated and more fully described. This system is very convenient for party lines, as nobody except the party desired is called, and consequently there is no mistaking of signals and not so much listening in by parties not called.

28. In many such systems, however, half or all the bells will give a single tap when the ringing current is first applied to the line. In central-energy systems, a high resistance, 3,000 to 20,000 ohms, may have to be connected in series with each bell so that the line resistance may be high enough to insure the operation of the regular exchange signals.

Biased bells can be rung with a sufficiently strong alternating current, because an impulse in one direction will act against the spring while an impulse in the opposite direction will assist the spring. Furthermore, alternating current will ring a bell no matter in which direction the bell is biased; hence, alternating current cannot be used to selectively ring only one of two biased bells connected to the same circuit.

THE HIBBARD SYSTEM

29. Circuits.—In Fig. 7 is shown a party-line system devised by Angus S. Hibbard, which depends for its operation on the placing of two oppositely biased bells between each side of a metallic circuit and ground. This system is arranged to operate on the common-battery

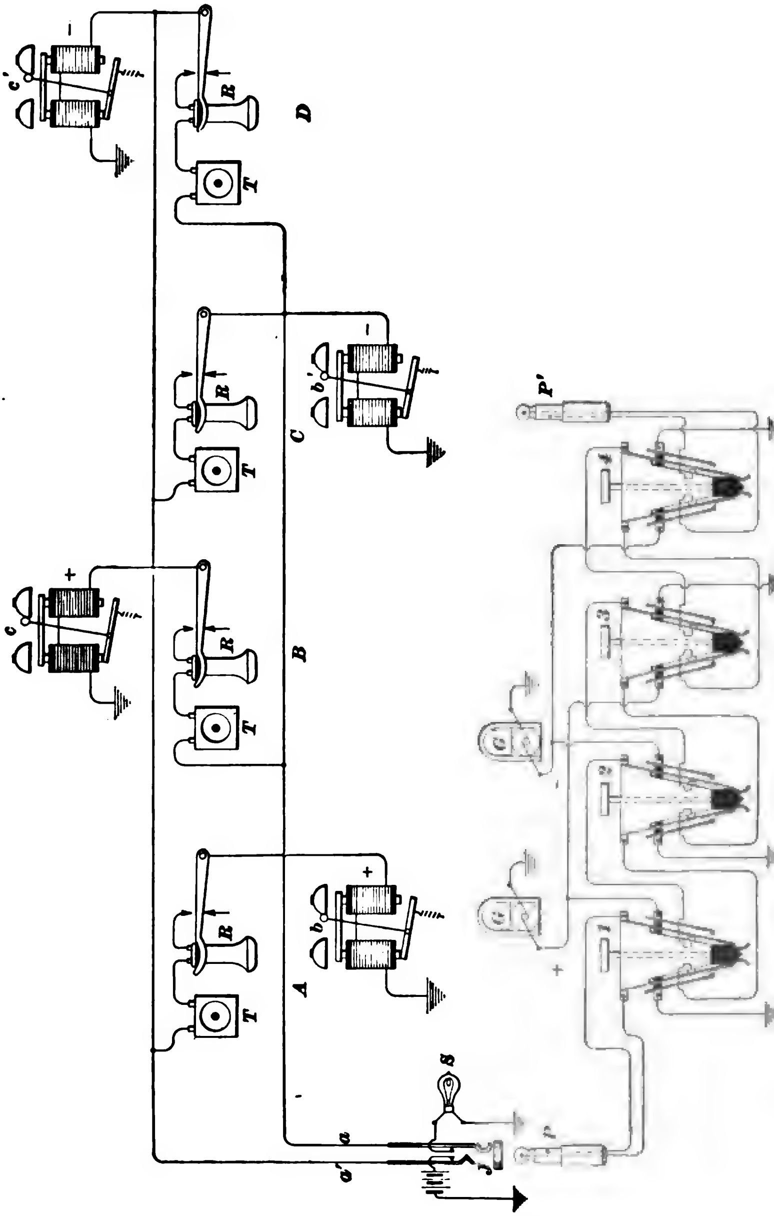


FIG. 7

principle, both for talking and for signaling, but for the sake of simplicity the talking circuits have been omitted at the central office. *A*, *B*, *C*, and *D* are subscribers' stations, having talking apparatus consisting of receivers *R* and transmitters *T* adapted to be bridged across the two sides *a*, *a'* of a metallic-line circuit. Between the line wire *a* and the ground at station *A* is bridged a polarized bell *b* adapted, by the use of a biasing spring, to be rung only by pulsating currents in a positive direction over the line wire *a* with a ground return. At station *C* is connected, in a similar manner, a bell *b'* adapted to be rung only by currents in a negative direction. Connected between the line wire *a'* and ground, at stations *B* and *D*, are polarized bells *c*, *c'*. The bell *c* at station *B* is adapted to ring only by currents in a positive direction sent over the line wire *a'*, using a ground return, and the bell *c'* at station *D* will only be rung by negative currents sent over the same circuit. The side *a* of the line wire is normally grounded at the spring jack *J* at the central office through the signal *S*, while the other side *a'* is similarly grounded through a battery. When, therefore, any subscriber removes his receiver from its hook, the signal lamp *S* lights up. The line signal *S* may be operated in any approved manner.

30. Operation.—Connected with the cord circuit of the plugs *P* and *P'*, Fig. 7, are four ringing keys *1*, *2*, *3*, *4*, adapted, when depressed, to connect one or the other of the call generators *G*, *G'* with one side or the other of the cord circuit. The connection of the various springs and anvils of these keys should be apparent from the diagram. If key *1* is depressed, the positive side of generator *G* will be connected with the sleeve side of the cord circuit, and therefore with the side *a* of the line circuit, into the jack of which the plug *P* is inserted. When, therefore, this key is depressed, a current will pass from the positive terminal of generator *G* to the line *a*, from which it will pass to ground through the bells *b*, *b'* located at stations *A*, *C*. Only bell *b* will be rung, because its armature alone is biased in the right direction to

respond only to positive currents. The bell b' will not ring, because it responds only to negative currents. Pressure on key *2* will similarly connect the negative terminal of the generator G' with the line a, thus sending a negative current to that side of the line, which will operate the bell b' and not the bell b. In a similar manner, the keys *3* and *4* are adapted, when depressed, to send positive or negative currents to the line a', thus ringing the bell at station B or station D, according to the direction of the current.

31. In some of the first systems operated on this plan, considerable trouble was experienced, due to the following cause: When a subscriber's receiver was removed from its hook, a low-resistance path was closed between the two line wires at his station; and if at this time a signal was sent from the central office it would ring a bell on each line. Thus, if the receiver at station C were removed from its hook and it was desired to call station A, a positive current sent over the line wire a would ring the bell at station A in the proper manner, but it would also pass through the talking apparatus at station C to wire a, and then pass to ground through the bell c at station B, causing it to ring also. This trouble has been effectually removed by causing the ringing keys to ground that side of the cord circuit that is not being connected with the generator. This prevents the ringing of a bell on the opposite side of the line, by providing a shorter circuit to the ground at the central station through the other line wire, over which the current may pass instead of passing through the high-impedance bells. To illustrate this, the case may be again assumed where it is desired to ring the bell at station A, while the receiver of station C is off its hook. Key *1* will be depressed, which will send current over the line a and ring the bell b at station A. Some current will pass through the talking apparatus of station C to the line wire a', but instead of this current passing through the magnets of bell c at station B or c at station D, it will return through line a' to the central office and pass to ground through a contact in the key.

32. About all telephone manufacturing companies are now prepared to supply apparatus for two- and four-party lines resembling the Hibbard system. They may differ somewhat in details but are the same in principle.

A representative four-party selective-signaling system using a master selective-ringing key and biased bells is shown in Fig. 8. Two biased bells are connected between each line wire and the ground. At the central exchange, each cord circuit is equipped with one regular ringing key Rk, and each operator's position is equipped with one set of ringing keys R_4, R_3, R_2, R_1, and R, called a **master ringing key.** If the operator desires to ring the bell *3*, she inserts the calling plug in the jack, sets the master key to give a positive pulsating current over the tip side of the cord and line circuit, which is done by closing key R_3, and then closes the regular ringing key Rk. In a similar manner, bells *1*, *2*, or *4* may be rung by closing the key Rk and R_1, R_2, or R_4, respectively. When either R_1 or R_3 is closed, a pulsating current flows through the tip side of the line, two bells, and ground to g; and when either R_2 or R_4, a pulsating current flows through the sleeve side of the line, two bells, and ground to g. The direction of the current through each line in each case depends on which key is closed. Non-selective ordinary bells connected directly across the line circuit are rung by an ordinary alternating current, which may be obtained by closing keys R and Rk. In order to avoid short circuits, the selective-ringing keys must be so arranged mechanically that the act of closing any one key will first release any other key that may have been previously closed.

33. In order that the selective-ringing currents may all be supplied by one generator, the latter may be connected about as shown in Fig. 8 (a), in which C represents the armature winding, n one segment and m the other segment of a two-part commutator, and o an insulated slip ring or pin, all of which revolve with the shaft, while d, e, and i represent stationary brushes. The circuit C–w–o–i–l–q–v–C is the

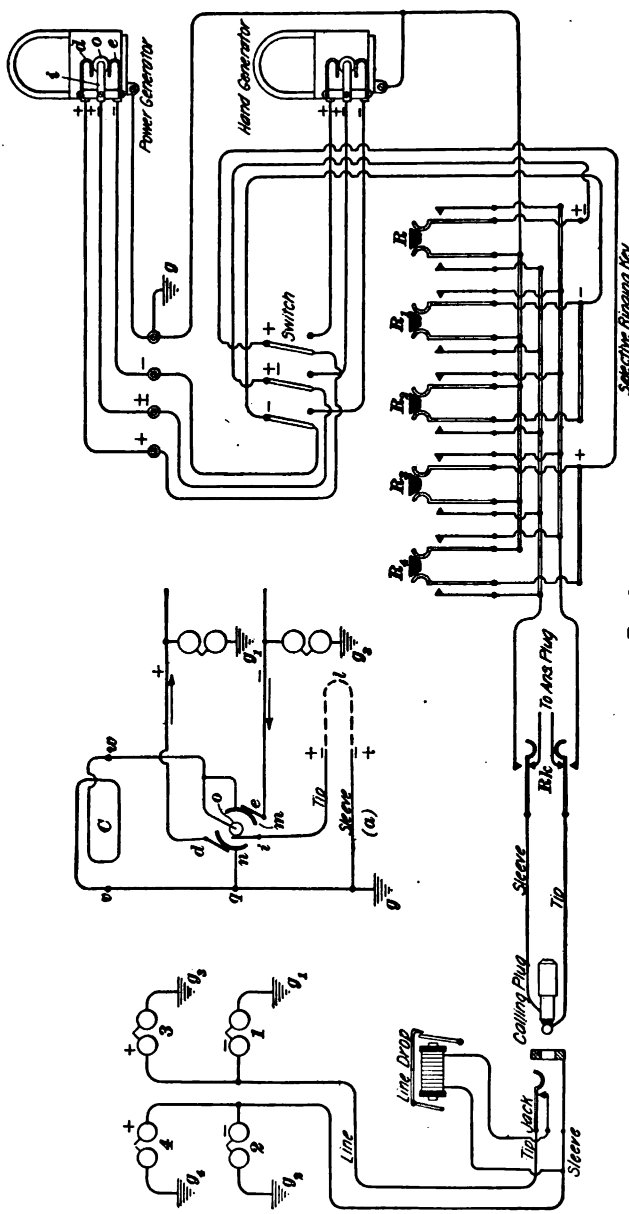

Power Generator
Hand Generator
Switch
Selective Ringing Key
To Ans Plug
Rk
Sleeve
Tip
Calling Plug
Line Drop
Jack
Line
(a)

FIG. 8

same as that of an ordinary magneto-generator, and hence an alternating current as indicated by the ± signs will be obtained in this circuit, which includes both wires of one line. In the position of the coil *C*, shown in Fig. 8 (*a*), let us assume that the electromotive force developed tends to send a current through the coil from *w* to *v*. Then, during this half revolution of the armature, a positive impulse may be obtained in the circuit w–v–g–g_2–e–m–w as long as *e* remains on the segment *m*, and also in *w*–*v*–*l*–*i*–*o*–*w* in the directions traced. Since *d* and *q* are now connected to the same end of the armature winding, the ground connection *q*–*g* practically short-circuits q–d–g_1 and consequently no current flows in the circuit d–g_1–g, while *d* rests on *n*. As soon as the armature rotates far enough to allow *d* to rest on *m* and *e* on *n*, the position of the coil *C* is reversed in the magnetic field and the electromotive force is reversed in direction so that current tends to flow from *v* to *w*, and its connection with the brushes *d*, *i*, *e* is also reversed; consequently, a positive current impulse may be obtained through the circuits *v*–*w*–*o*–*i*–*l*–*q*–*v* and v–w–m–d–g_1–g–q–v. Thus, current flows alternately in each direction through *l*, but only impulses in one direction through d–g_1–g, and in the opposite direction through e–g_2–g, there being an interval during which no current flows in one of the latter two circuits while the impulse is flowing in the other. In other words, the two-part commutator allows only the positive half of each complete period to flow out of the one brush *d* and only the negative half out of the brush *e* (really from *e* into *m*), each brush *d*, *e* conveying no current during half a period, that is, during half of each revolution. The end *v* of the armature and segment *n* may be permanently grounded through the shaft and frame of the generator.

34. Stromberg-Carlson Four-Party Selective-Ringing System.—Some four-party selective-ringing systems, using two biased bells between each line wire and the ground, give false signals on a line of considerable length, on account of the line resistance and the use of alternating

or pulsating currents that are strong enough to operate the bells, as well as the line signal at the switchboard. The Stromberg-Carlson Company claims to have overcome this defect by having each subscriber's generator send out a direct current of the same polarity as the bell of that station, and at the same time grounding the other side of the line so as to short-circuit the bells on that side while the subscriber is turning his generator.

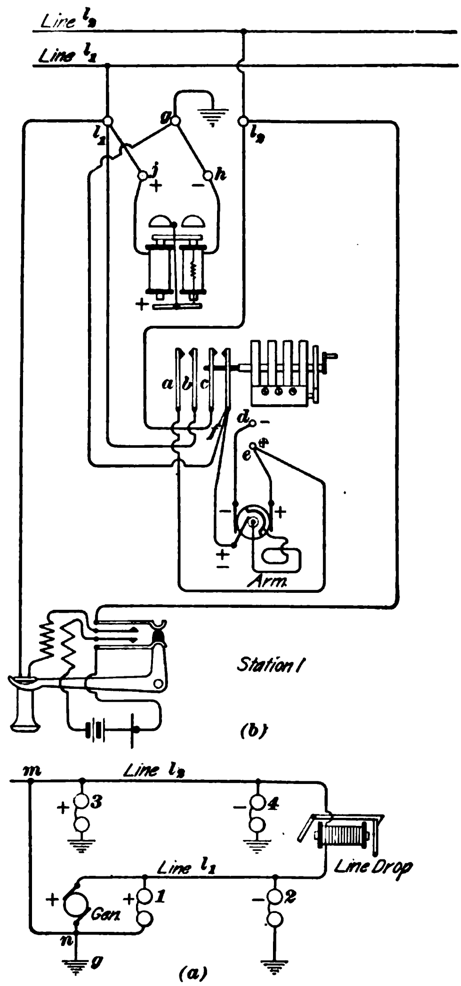


FIG. 9

The connections of one subscriber's telephone are shown in Fig. 9. Each telephone is equipped with a biased ringer, a direct-current hand generator of the four- or five-bar type, according to the work it is to perform, and the other necessary telephone apparatus. The ringer and generator are provided with flexible cords for making the necessary connections for each station and to allow for using the instrument at any station on the line; the instruments are thus interchangeable. In this arrangement, two biased ringers are bridged from each line wire to the

ground. Whatever line is connected to *e* will receive a positive pulsating current during each half revolution of the armature, and whatever line is connected to *d* will receive a negative pulsating current during the other half of each revolution of the armature. When the subscriber at station *1* turns his generator, the springs *f* and *c* touch each other, as do also springs *a* and *b*. These connections are shown, with all details omitted, in Fig. 9 (*a*). The positive pulsating current flowing from station *1* out over line l_1 will ring only the bell at station *1*, which is bridged across the generator, because it is in the right direction to ring that bell; it is in the wrong direction to ring the bell at station *2*, and will not ring the bells at stations *3* and *4*, because it will take the path of smaller resistance through line l_2 and connection *m*, *n* back to the generator at station *1*; furthermore, it will operate the line drop at the exchange, since the latter is connected in series with the line wires.

35. The generators are disconnected from the line when not in use. All four stations are provided with similar generators and bells biased and polarized in exactly the same way. The only difference between the stations lies in the connections made by flexible cords. At station *1*, Fig. 9, *j* is connected to l_1, *b* to l_1, *h* to *g*, *f* to *g*, *a* to *e*, and *c* to l_2; at station *2*, *j* is connected to *g*, *b* to l_1, *h* to l_1, *f* to *g*, *a* to *d*, *c* to l_2; at station *3*, *j* is connected to l_2, *b* to l_2, *h* to *g*, *f* to *g*, *a* to *e*, *c* to l_1; at station *4*, *i* is connected to *g*, *b* to l_2, *h* to l_2, *f* to *g*, *a* to *d*, *c* to l_1. By drawing the four stations and connecting them as just stated, it will be found that each generator sends a current into the proper line wire and in the proper direction to ring only the bell at its own station and operate the exchange drop. The connections at the exchange do not differ materially from other similar systems.

36. Kellogg Two-Party Selective System.—In Fig. 10 is shown a diagram of connections of the **Kellogg two-party selective system** as applied to the Kellogg central-energy multiple switchboard. The diagram shows the connections of all the signaling apparatus involved.

When ringing current is impressed on either side of the line, the bell on that side is rung and the other is not disturbed. When the called subscriber responds, the circuit to ground through the bell is broken and the conversation is held over a complete metallic circuit.

In the Kellogg two-wire multiple system, the cut-off relay *O* must be energized during the ringing, for which reason the ringing generator *G* is equipped to give negative pulsating current in addition to regular alternating current. When the operator pulls the handle of the two-party ringing

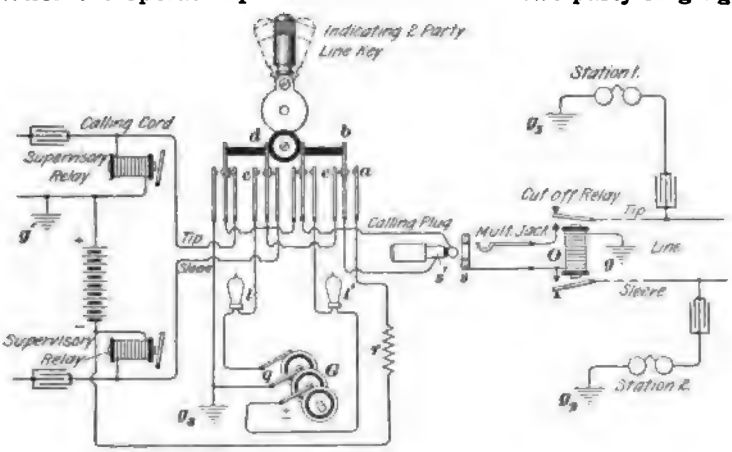


FIG. 10

key toward her (to the left in this figure), alternating current is sent out from the generator terminal marked ± through l'–tip side of the line–station *1*–g_1–g_3. At the same time, a circuit is closed that allows current to flow from battery *B* through g'–ground–g–cut-off relay *O*–*s*–s'–*b*–*a*–*r*, to hold the cut-off relay closed. When the operator pushes the handle of the ringing key from her (to the right in this figure), negative pulsating current flows from the generator terminal *q* through *l*–*c*–*d*–*e*–*b*–s'–*s*–sleeve side of line to ground at station 2 where, through the action of the condenser, it acts like an alternating current; that is, it causes the condenser to alternately charge and discharge, thus ringing the bell. Part of the pulsating current takes a branch path

to ground through the cut-off relay and holds it closed. A subscriber with an individual line is signaled by pulling the key in the same direction as when ringing station *1*. Each cord circuit is equipped with the selective-ringing key, as shown in this figure. G represents a power-driven generator of alternating and pulsating currents that supplies all the ringing current for the whole exchange.

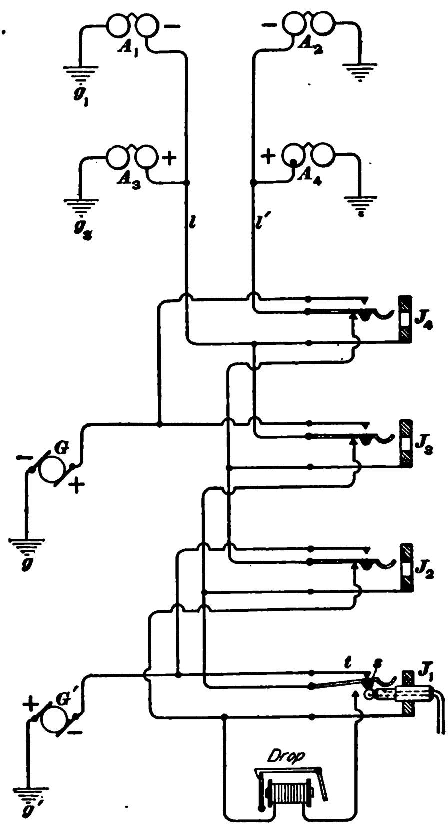


Fig. 11

37. The Cook Selective-Signaling System.—A four-party selective-signaling system devised by F. B. Cook is shown in Fig. 11. There is one line jack for each station on each party line and the ringing is accomplished by merely pushing the plug into the jack as far as it will go, which allows one of two generators G or G' to send a pulsating direct current through one of the line wires, two subscribers' stations, and the ground. When the plug is released, it returns to its normal position. When a plug is pushed all the way into the jack J_1, the negative terminal of G' will be connected to line l, thereby allowing pulsating direct currents to flow through $G'-g'-\left\{\begin{matrix} g_1-A_1 \\ g_3-A_3 \end{matrix}\right\}-l-s-t$. Since this current flows from the substation back through the line to

the exchange, it is called a *negative pulsating current* and the bells are so biased by a spring that only A_1 will respond to current in this particular direction. By inserting the plug in jack J_2, the bell A_2 only will ring. Similarly, by inserting the plug in jack J_3 or J_4, only the bell A_3 or A_4, respectively, will ring. Only the bells are shown at the subscribers' stations, but the talking circuits, which are here omitted for clearness, may be connected across the two line wires in any suitable manner.

By this arrangement, there is one jack for each station, and the operator, in order to ring the proper bell, has only to insert the plug into the jack whose number is called for; no ringing keys of any kind are required in the cord circuits. However, the jacks are rather complicated and a generator lead has to be carried to each party-line jack. Although shown for a simple switchboard only, the system can be adapted to a multiple switchboard. This system has not proved very successful and, in fact, the Bell Company, after a fair trial, abandoned an arrangement based on the same principles.

THE BARRETT-WHITTEMORE-CRAFT SYSTEM

38. A very promising system for selective signaling on party lines adapted for a greater number of stations than four was devised by Messrs. Barrett, Whittemore, and Craft. This system, although extensively used at one time in many Bell exchanges, is being abandoned because of its great complexity, the difficulty of keeping it in adjustment, and on account of the increasing use of central-energy systems to which it is not readily adaptable. It depends for its operation on the sending of currents in either direction over either or both sides of a metallic-line circuit, in combination with each other or the ground.

39. Principles of Operation.—The fundamental principles on which the operation of the system depends are shown in Fig. 12, in which a, b represent a metallic-circuit line, and R, R' two relays at a subscriber's station, R being connected between the line a and the ground G', and R' between the line b and the ground G'. B is a battery and G

is a ground at the central office. By using the ground as a third conductor, four circuits may be obtained from the central office. One of these includes the line wire *a* with the ground return; a second, the line wire *b* with the ground return; a third, the line wires *a* and *b* as a metallic circuit, not using the ground circuit at all; and a fourth, the line wires *a* and *b* in multiple with the ground return. The

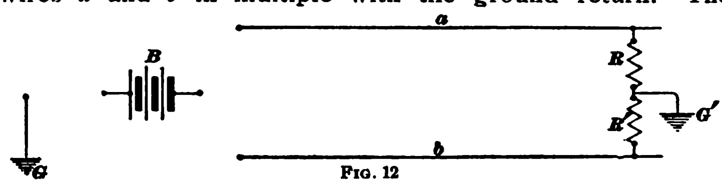


FIG. 12

battery *B* at the central office can be connected by a proper manipulation of switches in any one of these four circuits, and each of them will include one or both of the relays *R*, *R'*. Obviously, the four circuits obtained from the two conductors and the ground might be used for obtaining four selective signals from the central office to the various subscribers' stations, all equipped with relays *R*, *R'*. If both of the relays *R*, *R'* are polarized, the number of selective signals obtainable is doubled, for the battery *B* can then be connected so as to send its current in either direction through any one of the four circuits mentioned.

40. It is by means of these four available circuits, and by a proper choosing of the direction of current through them, that selective signaling is brought about in the **Barrett-Whittemore-Craft system.** The two relays at each station control one circuit containing a primary battery and an ordinary vibrating battery bell. In order to secure means for locking out the instruments of all the subscribers on the line, except the one who is actually using it, two of the current combinations are reserved for controlling the locking and unlocking mechanisms. This leaves but six combinations for signaling purposes, and this system is therefore usually equipped for that number of stations. Since this system is no longer being installed, it is unnecessary to give a more complete description of it here.

PARTY-LINE SELECTIVE-RINGING KEYS

41. Where selective-ringing party lines are extensively used, each pair of cords in the exchange should be provided with party-line ringing keys having indicators to plainly show which key had been used last. This enables the operator to again ring the desired subscriber with the same key as before, in case the first ring is not answered, as would be indicated in a central-energy system by the failure of the calling supervisory signal to operate. If an indicating device is not provided, the operator may often be compelled to request the calling subscriber to repeat the number that he previously called for. This is undesirable because the subscriber may have forgotten the number or he may attribute the request to carelessness on the operator's part.

Instead of providing each cord circuit with a complete set of selective ringing keys, one master key may be provided at each operator's position. The master key controls and may also indicate what selective ringing current would be obtained if the ringing key on any cord circuit is closed. Even if the master key is provided with an indicator, this does not show what cord circuit it was last used on and, although the supervisory signal will indicate what party has not answered, the master key may have been set for a different ringing current since the party failing to answer was first signaled. Hence, the operator is not much better off than without the indicator on the master key. One master key is, of course, cheaper to instal than a complete set of selective-ringing and indicating keys for each cord circuit. However, when it is not the intention to go into the party-line business extensively, a master key may be used.

42. Position of Contacts.—In manually operated keys, where strong pressure can be exerted on the contacts, it is not necessary that other than the talking contacts be of platinum. Ringing and other signal contacts, unless they carry very low voltages, may readily be made of German silver. It is advantageous, however, in such cases, to have saw teeth

in the end of one of the springs in order that a plurality of contacts may be present. In keys, jacks, and other devices having contact springs, the latter should be set edgewise and not flatwise horizontally, because the collection of dust and lint, which interferes with good contact, is very much less with the edgewise arrangement.

43. Cleaning of Contacts.—It is not advisable to clean contacts with files, emery, or crocus cloth, because the former wears the contacts too much and all are apt to produce metallic and insulating dust that later causes trouble. The proper tool for such cleaning may consist of a small piece of spring steel, such as part of a clock spring, from $\frac{3}{8}$ to $\frac{1}{2}$ inch wide and 6 inches long. Grind its flat sides crosswise on a fine emery wheel; as it is very hard, it will now have a surface resembling ground glass and will be a finer file than can be purchased. To clean a key contact, operate the key so as to separate the points, pass the spring blade between them, close the contacts, withdraw the spring gently, and the contacts will usually be clean.

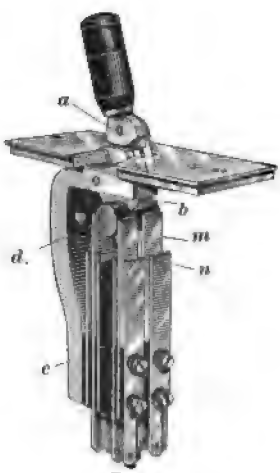


FIG. 13

44. A Kellogg individual selective-ringing and indicating key is illustrated in Fig. 13. It is self-restoring from either position, but has a lost motion that causes the handle only to remain tilted in the direction last operated. Should it be necessary to ring a subscriber a second time, the operator will know from the tilt of the lever which party is wanted.

The upper part of the piece *b* is slotted and arranged to receive the lower end of the operating handle, which has a flattened head *a* secured in the slot by a screw. While the head *a* is permitted to move back and forth, the engagement between it and the sides of the slot is close enough to cause the same to frictionally bind and therefore prevent its

moving unless manually operated. The amount of independent movement of the handle, or the lost motion between it and the cam *b*, is determined by the shape of the lower edges of the portion *a*. These edges strike the bottom of the slot in the piece *b* when the handle is tipped slightly to one side or the other from the vertical, and a further movement of the handle causes the cam or lower part *d* of the lever to be pushed over. Four sets of switch springs are carried by the vertical portion of the frame, two sets *m*, *n* side by side and the other two sets similarly located on the opposite side of an insulating block *c*. The free ends of the long, or center, springs of the opposed sets stand on opposite sides of the key lever or cam-block *d*, and tend to keep it in its central position. These springs normally touch the inner springs of the sets; but when pressed outwardly, they move out of contact therewith and into contact with the outer springs. The Kellogg master ringing key is similar, in construction, to the individual key.

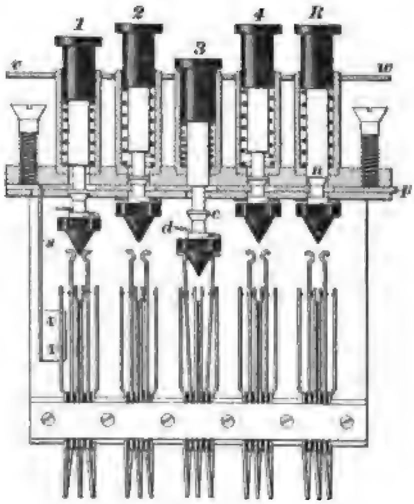


FIG. 14

45. The **North selective-ringing individual key** is shown in Fig. 14. The spring *s* tends to keep the plate *p* pressed to the right. Key *1* is shown in its indicating position, and key *3* in its ringing position. The depression of a key causes the conical surface *c* to push the plate *p* to a central position, so that *c* can pass through. When the key is released and *c* rises, its upper flat surface strikes the plate *p*, which has in the meantime been pushed back to its normal position by the spring *s*, and hence the key remains

in the position shown at *1*. The depression of the key *R*, which is used to ring on a private line, will restore any other key to its normal position. It will be noticed that *R* has no flat surface at *n*, hence it will not remain out of its normal position. The springs *d* prevent a sudden jar as the keys are restored to their positions. The insulating material between the German-silver springs, all of which have platinum contacts, is mica.

46. The **Dean four-party selective-ringing key** and a single listening key are shown in Fig. 15. The only con-

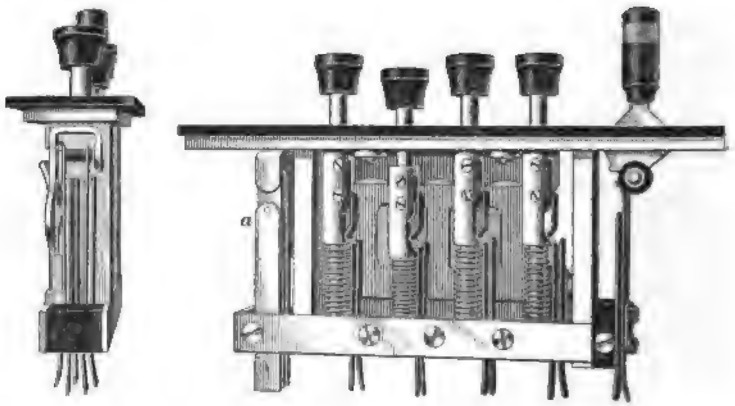


FIG. 15

tacts in the talking circuit due to this key are mounted at the front *a*, where they are in plain view when the shelf is open. Closing any ringing key opens the circuit at *a* toward the answering side of the cord circuit.

47. Stromberg-Carlson Selective-Ringing Key. An individual selective-ringing and indicating key for use in each cord circuit where four-party-line, positive-and-negative, pulsating-current systems are employed is shown in Fig. 16. When she receives a call, the operator presses the cam-lever *k* to the listening position *L*, and, having then selected the ringing button corresponding to the subscriber desired, she presses it into the locking position, as shown at button *4*, the contact springs of which are omitted to better show the

construction of the conical pieces *c*, *i* and the spiral spring *t*. When depressed as far as it will go, the button closes the proper ringing circuit, and the cam *c*, by pushing the sliding plate *s* into a central position, causes the pin *f*, which is fastened to *s*, to push the pin *e*, thereby returning the lever *k* from its listening position to its normal and central position to which a spring *n* always tends to return it. The operator then rings by pushing lever *k* to the ringing position *R*. Button *4* will be automatically restored to its normal position when the lever *k* is again turned to its listening position, because the

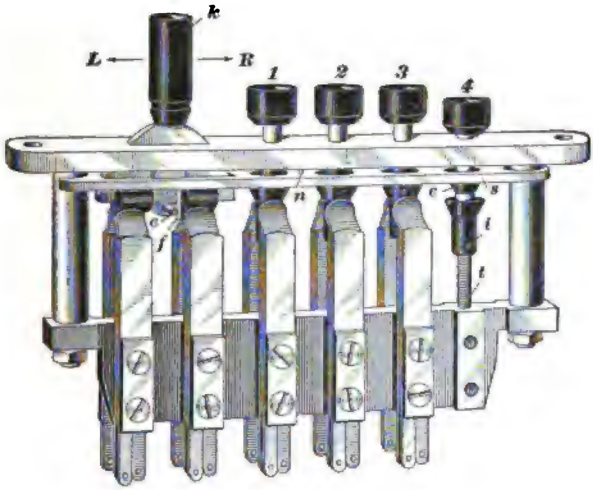


FIG. 16

pin *e* pushes the pin *f* and the plate *s* to its central position, so that the hole in *s* coincides with conical piece *c* on the button rod, thereby allowing the conical piece *c* on any depressed button to be pushed upwards by its spring *t* through the hole in *s*. A spring *n* tends to keep the plate *s* to the left side of its central position. The over-all height of the key is 5½ inches and its length 7 inches. The key is so constructed that only two contacts are included in the talking circuit by its use. This is readily arranged because the ringing leads are only connected to the calling plug when the lever *k* is held in the ringing position *R*. All contacts are tipped with platinum.

48. Stromberg-Carlson Selective-Ringing Master Key.—A selective-ringing master key is suitable where it is desired to add a party-line system to a switchboard and regular cord equipment already installed. The master key manufactured for this purpose by the Stromberg-Carlson Telephone Manufacturing Company is shown in Fig. 17. It consists of five indicating push buttons, the four marked *1, 2, 3, 4* being for party-line service, the one marked *A C* for private lines on which alternating current is used, and one release push button *R* for releasing any key that may be down. If the operator desires to ring with the usual alter-

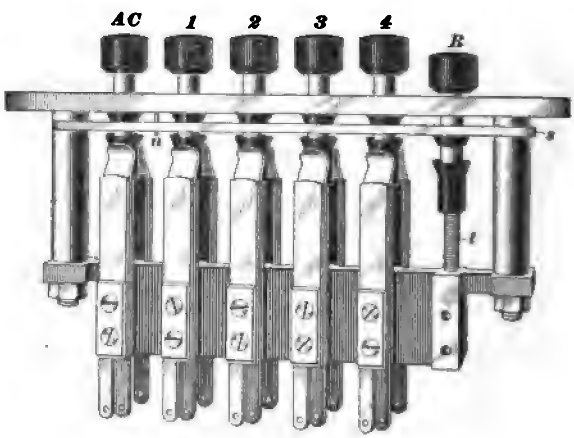


Fig. 17

nating current, she will first depress the key *A C* and then the regular ringing key in the cord circuit. If, the next time, she desires to ring party *2* on a selective four-party line, she will depress key *2*, which will release the key that has previously been depressed, in this case the key *A C*, and then depress the regular ringing key. The construction of this key is similar to one previously explained.

49. Western Electric Party-Line Ringing Key. With many party-line ringing keys, it is necessary to talk through two contacts for each key in the set, which is a disadvantage. To overcome this, F. R. McBerty has

devised, for the Western Electric Company, the key circuits shown in Fig. 18. One pair of cut-off contacts at *O* serves for all the ringing keys, this cut-off key being controlled by a master bar *a*. *R k* represents a key for applying ordinary alternating current to the line for ringing ordinary polarized bells, while keys *1*, *2*, *3*, and *4* are used for party-line selective ringing. When any one of the five keys is operated, the

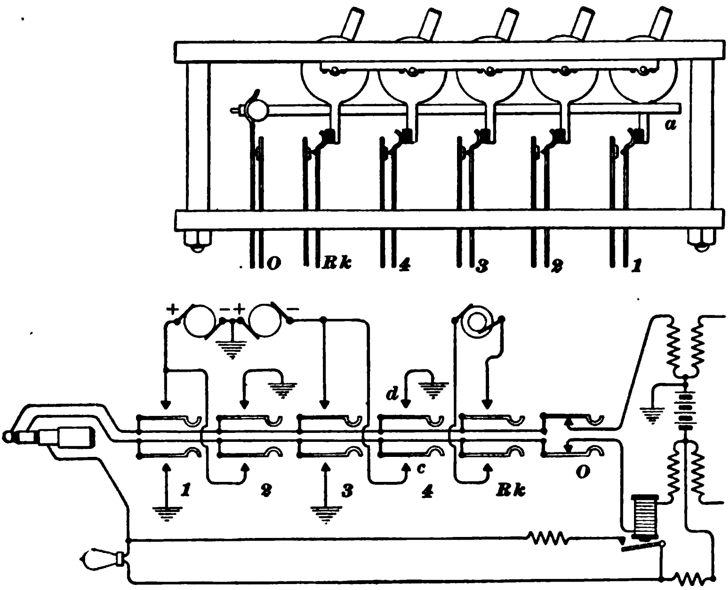


FIG. 18

circuit is first opened at *O* on the common-battery, or exchange, side of the circuit. For instance, when key *4* is closed, the ringing current passes only through contacts *c*, *d*. In other words, the contacts on the various ringing keys are not in series, but rather in a multiple combination. The Dean and Stromberg-Carlson individual selective-ringing keys are connected in about the same manner.

DISADVANTAGES OF BIASED-BELL SYSTEMS

50. One objection to biased bells is the difficulty in making them ring properly at all times, due to variation in spring tension, variation in voltage of ringing generators, and variation in frequency of the ringing current. It is also impossible to use a condenser in series with a biased bell, because the charging and discharging of the condenser produces the same effect as an alternating current, so that the ringer will respond to currents of either polarity. This is a serious objection against the use of biased bells on central-energy systems.

Furthermore, there are several objections to party-line systems using biased bells connected directly between one side of the line and ground: first, it costs something to install and maintain earth connections; second, when a subscriber removes his receiver from the hook while his bell is ringing, the bell of like polarity or frequency on the other side of the line also rings, unless the resistance of that line wire back to the exchange is very low; third, bad inductive and leakage troubles are very apt to be caused by the earth connections, unless the earth connections exist only during ringing, as in the Thompson or similar systems; and fourth, they cause, on central-energy systems, a constant loss of current through the line relay and the bells connected in multiple between one line wire and the ground, because one side of the common battery is always grounded. The latter objection is overcome by the Thompson system because a bell is connected to ground only when its relay, which is connected in series with a condenser across the line wires, is closed. However, the Thompson arrangement increases the cost of subscribers' instruments and introduces relays that are likely to cause trouble.

51. Cause of Single Taps of Bells on Some Party-Line Systems.—The two-party-line system using an ordinary polarized bell and condenser in series between each side of the line and the ground is not entirely selective,

because the bell on the wrong side of the line will usually give a single tap when the desired bell is rung, which serves to tell the undesired subscriber that something is going on and hence a temptation arises to take down the receiver and listen. This may be explained as follows: The operator, having inserted a plug across the cord circuit to which the battery is connected, into a jack, has caused the condensers to become charged. A moment later, when operating the ringing key, the battery is disconnected momentarily and the side of the line to which the ringing generator is not connected is opened, and in most cases also grounded; consequently, the condenser of the telephone not desired discharges through its own bell in either case and the bell gives one tap.

In order to make biased bells absolutely silent when current impulses, which are not intended to ring them, pass through them, the pivot should have no end play at all; if it does, there will be a rattling sound. The adjustment should be such that in the normal, or at-rest, position one end of the armature rests against one pole of the magnet, while the clapper does not touch the gong.

52. Biased Bells on Central-Energy Systems.—The practice of the Bell companies is to adjust their line and supervisory relays so as to operate on 24 volts through a resistance of 750 to 1,000 ohms and, after being operated, to be restored if the resistance is increased to 10,000 ohms. On a party-line system having two bells connected between each side of the line and the ground, it is, therefore, necessary to have the joint parallel resistance of two bell circuits between the ground and the side of the line that is connected through the line relay and battery to ground equal to or greater than 10,000 ohms. If such is not the case, the supervisory relay will, in all probability, remain energized and no disconnect signal will be given. To avoid this trouble in party lines using no condensers between the bells and the ground, it is the custom to wind each bell to a resistance of 2,500 ohms and to include in series with each bell, or at least in series with the two on the side connected through the line

relay and battery to ground, a non-inductive resistance of 20,000 ohms.

53. Trouble on Selective-Ringing Systems.—It will not be possible to consider here all kinds of trouble that may occur on selective-ringing systems, but merely a few to which they are particularly subjected. In central-energy systems, metallic circuits with protecting heat coils in each side of the circuit are generally used, and, moreover, one side of the battery is generally grounded. Prof. J. C. Kelsey, in Telephony, says that, where the heat coils are arranged to ring a bell or work an annunciator when they operate, this trouble can be readily detected; but in many systems no indicators are used. When this is the case and a heat coil on the side of the circuit not grounded operates and grounds the switchboard side of the circuit, the line signal will remain displayed until the ground is cleared. On multiple boards, the operator at any section, except where the line signal is displayed and can be seen, might try to ring up the subscriber on that side of the line and, failing, report trouble to that effect.

If the heat coil on the grounded-battery side operates, the line signal will not be displayed and trouble will only be evident when an operator is unable to ring the bell of a subscriber connected between that side of the line and ground, because if the switchboard side is grounded at the heat coil this ground short-circuits this bell, nor can the bell be rung if the switchboard side is opened at the heat coil. Furthermore, on repeating-coil systems, a ground anywhere, in addition to the permanent one at the battery, practically short-circuits one winding of the repeating coil, and the subscriber generally complains because he can scarcely hear or make himself heard. When the ground at the heat coil, or elsewhere, is removed, both the ringing and transmission troubles are cleared. When alarms are not used to indicate the operation of a heat coil, a daily inspection of the coils should be made.

54. On four-party pulsating systems, the complaint "bell does not ring" is much more common. In addition to the

trouble due to grounded heat coils, the improper adjustment of the bells is the cause of considerable trouble. If the bells are adjusted for a certain speed and voltage of the ringing generator, they may fail to operate properly if there is sufficient change in one or both of these conditions. This frequently occurs where the ringing current is supplied by a motor-generator outfit that is driven by current from a power circuit, the voltage of which is subject to considerable variation, or where one machine is used during the day and another at night, or where the machine is operated by storage batteries that gradually run down between morning and night. If the bells are adjusted in the morning, they may fail to ring at night, and vice versa. Bells are commonly adjusted so that a turn of one-eighth of a revolution of the adjusting screw will stop the ringing of the bell. However, they usually can and should be adjusted with such a wide range that they will continue to ring if the screw is turned about five-sixths of a revolution. It is best to determine the angle through which the screw may just be turned without stopping the ringing of the bell, and then to set it half way between the extreme limits. This will usually give the bell sufficient range for all ordinary variations of the ringing generator.

55. Use of Polarization Cells.—Where poor ringing is due to the change in voltage of the storage battery that supplies current for running the motor generator, so-called **polarization cells**, containing storage-battery solution and unformed, lead, storage-battery plates, may be used to keep the voltage applied to the motor more nearly constant by being inserted in the motor circuit. They will develop a potential opposing that of the driving current, and thus reduce the effective potential at the terminals of the motor. This reduction is about 2 volts per cell, increasing or decreasing somewhat as the driving current increases or decreases. These cells may be inserted in the circuit one at a time, automatically or by hand, after the beginning of the charge, and again cut out as the cells discharge; it is thus practical to limit the maximum variation to about 2 volts.

56. Variations in the ground resistance due to poorly grounded terminals, usually at the subscribers' stations, may also interfere with the proper ringing of the bells. Where the ground wire is fastened to a pipe in the house, it should be soldered, otherwise it may corrode. When the trouble is due to this cause, the inspector frequently readjusts the bell, which only eliminates the trouble for a short time. When the ground connection becomes more corroded, another adjustment is required, whereas the proper repairing of the ground connection would have permanently cured the trouble.

Sometimes the difficulty in properly ringing the bells is due to the fact that the operator does not hold the ringing key closed firmly enough or long enough. If the current from a street-railway system finds a return path through the telephone line, it may seriously affect the ringing of the bells. This will depend on the relative direction of the foreign current through the telephone line and also on its relative strength compared with the ringing current. About the only remedy is to prevent the flow of the foreign current through the telephone line by improving the conductivity of the return circuit of the railway system.

57. A Differentially Wound Ring-Off Drop.—In changing over an exchange from private lines to selective-

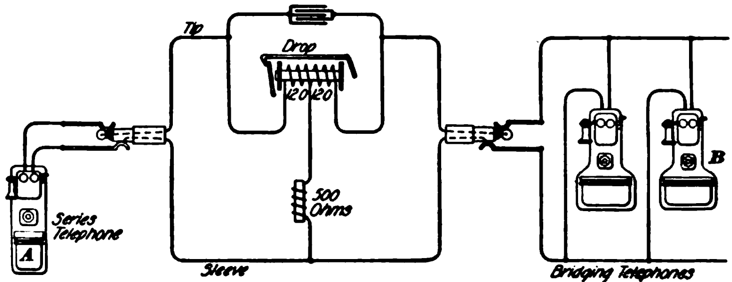


FIG. 19

ringing party lines using 2,500-ohm biased ringers, it is sometimes difficult, according to a writer in the American Telephone Journal, to make the ring-off drop work in a reliable manner. When a single-line 80-ohm telephone *A* is connected with a party line *B*, it might be impossible for *A*

to ring off, although any party on line *B* can always do so; and if, as is very often the case in starting party lines, there is but one telephone on the party line, this one telephone *A* will be hung up and entirely out of service if a *B* subscriber neglects to ring off. In Fig. 19 is shown an arrangement that may be used to overcome this trouble and still give a good, reliable ring-off drop under all conditions. The ring-off drops have two windings, each containing 3,500 turns of No. 34, single, silk-covered, copper wire, giving each winding a resistance of about 120 ohms. The center of the winding of the ring-off drop is connected to the sleeve side of the line through a 500-ohm impedance coil. If two single 80-ohm telephones are connected through the exchange, each rings off principally through the two low-resistance series-windings of the drop, the impedance coil receiving little or no current. In case two bridging party lines, like *B*, are connected together, they will ring off through one winding and the bridged coil almost entirely; and if a series-telephone *A* and bridging telephone *B* are connected together, *B* will ring off through the bridged circuit, while *A* will ring through the series-circuit. As the different paths are cumulative in effect, it makes a very sure ring-off for magneto-systems on the mixed lines so largely used.

58. Repeating Coil and Ring-Off Drop.—If it is desirable to have a single ring-off drop that may be operated by a generator in either of two lines connected together through a repeating coil in a cord circuit, the drop may be arranged as follows: In the center of each winding of the repeating coil, connect a condenser, and around each condenser connect one of two coils wound on the same ring-off drop. Of course, two entirely separate drops, each with one coil, may be used.

BUSY TEST ON PARTY LINES

59. If one subscriber on a party-line system asks for another subscriber on the same line, there is apt to be trouble in some party-line systems, to avoid which the

operator must know that she is dealing with a party line. If the operator plugs into the multiple jack of the party line in the answering jack of which her answering plug is inserted, she will get the busy test and will tell the person calling that the telephone called for is busy, if she does not know that the number called for is on the same line with the calling subscriber. Such calls are termed **reverting calls.** If it is found that two parties on the same line call each other frequently, they can be instructed to call as follows: "Give me the *C* party on my line," or other letters as requested. If the terminal, or unit, figure of the number designates the party, as 1351, 1352, 1353, 1354, which means that the line jack is 135 and that the terminal figures 1, 2, 3, or 4 designate the party ring, some system of marking the answering jacks and signals will overcome the trouble. A good method is to mark the line signals of all party lines with some distinct mark that the operator cannot fail to see when she inserts the plugs; also, place the subscribers' number or numbers, if there are two numbers, on the answering jacks or signals, in order to show the operator that the call is from a party line. It is also well to mark the multiple jack so as to remind the operator to ask for the party desired and to use the proper party-line ringing key if the subscriber fails to give the terminal letter, where both letters and numbers are used, as 135C.

EFFECT OF LONG LINES AND PARTY LINES ON LINE RELAYS

60. In 22-volt central-energy systems, a 100-ohm line relay should operate if the resistance of the line circuit falls to 2,500 ohms or less. On a central-energy four-party line consisting of two 2,500-ohm bells between each line and the ground, it is quite customary to connect a resistance of 3,000 ohms in series with each bell; this will give a resistance of about $\frac{5500}{2} = 2{,}750$ ohms between each line and the ground. This will come too near operating a 100-ohm line relay, and, moreover, the circuit will be very apt to become noisy, especially if it is in the path of return street-railway

currents. Furthermore, if one of the resistance coils should be short-circuited, either accidentally or by an attempt to keep a station having a burned-out coil temporarily in service, the resistance will only be $\frac{2,500 \times 5,500}{2,500 + 5,500} = 1,720$ ohms. Even if the line relay is adjusted not to operate on this resistance, the supervisory-cord relay will not give the clearing-out signal when the receiver is hung up, because the resistance through the line and bells will be too low. If, in the absence of the proper signal, the operator does not remove the plug, no subscriber on that party-line circuit can make any signal at the exchange.

61. On the other hand, a line of iron wire 20 or more miles in length, especially if it contains poor joints, may have a resistance of from 1,200 to 2,900 ohms, which alone would prevent the operation of an ordinary 100-ohm line relay. Furthermore, a long party line that is grounded through the bells or otherwise, even though properly transposed, will usually make a short grounded line with which it may be connected very noisy, because the long line is unbalanced.

The difficulties mentioned that occur in connection with both party-line systems and long lines may be overcome by subdividing the line between the intermediate and main frames, inserting there the proper repeating coils and relays. It is also better to subdivide the long and party lines so that all lines can be worked in a similar manner, thereby requiring no special cord circuits or the close adjustment of all relays to suit a few long or party lines. The following methods for remedying these difficulties were given by Prof. J. C. Kelsey, in Telephony.

62. Subdividing a Long Line by Repeating Coil. Fig. 20 gives a method of subdividing a long line by the use of a repeating coil w, x, y, z, two similar 100-ohm, or, if necessary, higher resistance, coils R, R' (R being a sufficiently sensitive relay to operate through a resistance of 3,000 ohms or less), two condensers C, C_1, and a resistance r of 10 ohms.

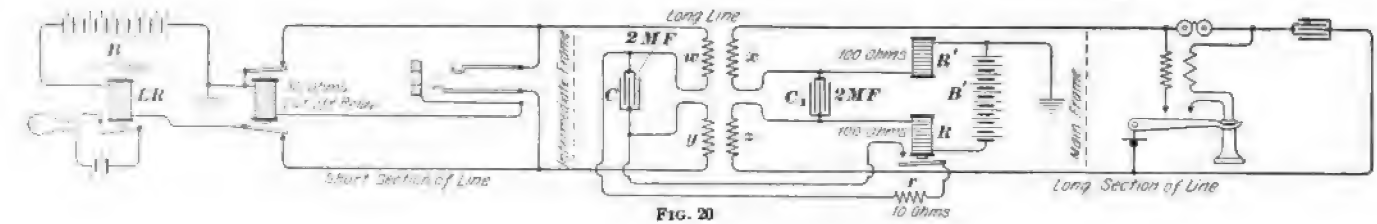


FIG. 20

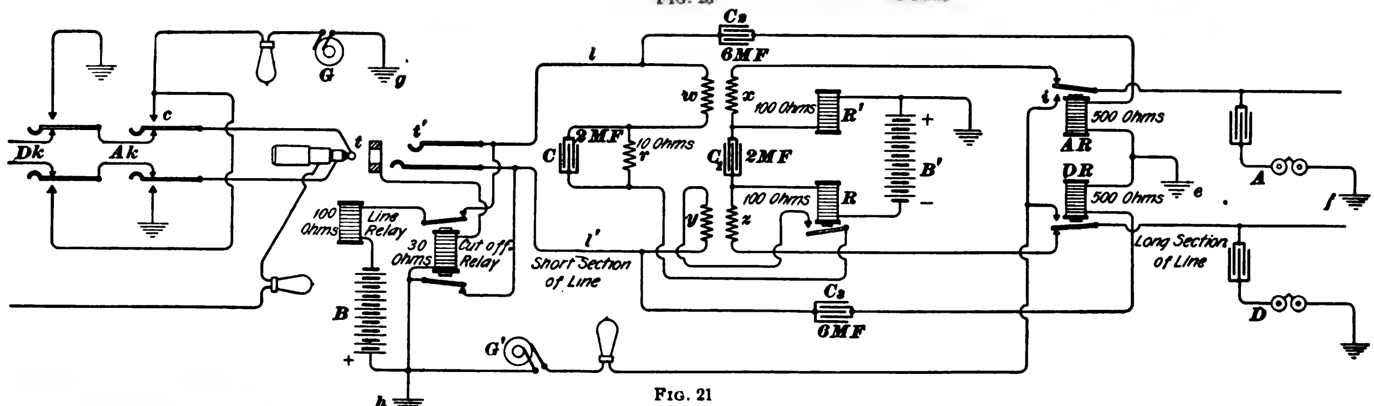


FIG. 21

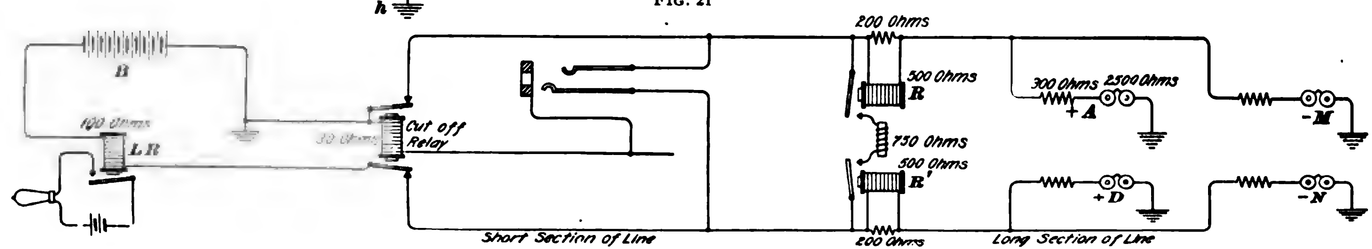


FIG. 22

The relay R being normally open, the exchange side of the line circuit is normally open because the windings w, y are then connected only by the condenser C. When the subscriber takes the receiver off the hook, current flows from B' through R, R' and the line; the relay R connects the resistance r across the condenser C, thereby allowing current from B to flow through and operate the regular line relay $L\,R$. The resistance r is necessary, for, if the condenser C is short-circuited by the relay R, the discharge is very apt to weld the relay contacts together and keep the line signal permanently displayed. The coil R', similar in resistance and inductance to relay R, is used merely to preserve the balance of the line, and the condensers C, C_1 form practically continuous circuits across the windings w, y and x, z for the ringing and voice currents. The repeating coil must be constructed so as to be sufficiently efficient for both ringing and voice currents. B is, of course, the same battery as B'. The repeating coil used in this arrangement enables the long line circuit to be connected through a regular cord circuit with a grounded line without making them noisy, due to what would otherwise be an unbalanced circuit. The subscriber's bell is rung by currents induced in the winding on the line side of the repeating coil and if ringing is weak the connection of two 2-microfarad condensers in parallel with C and C_1 will usually remedy the trouble. This arrangement is not suitable, however, for selective ringing on party-line circuits because only alternating currents can be generated in the windings x, z, no matter what kind of variable currents are produced in w, y. Nor can an alternating current be produced in only one of the two line wires with the ground as a return circuit.

63. Subdividing a Long Two-Party Line by Repeating Coil.—Long lines are generally used as party lines and selective ringing is desirable, but it cannot be obtained with the preceding arrangement. To provide for two-party selective ringing with alternating current (one telephone bell and condenser between each line wire and the ground) and still

have a circuit that will operate the regular line relay without special adjustment, the arrangement shown in Fig. 21 may be used. The apparatus is shown in its normal position, in which case, it will be noticed, w, y are not connected together at the center and the condensers C_1, C_2 hold the line-relay circuit open. In case subscriber A removes his receiver, thereby connecting his talking circuit across the two line wires, current from B' flows through $R R'$, thus connecting condenser C and resistance r, which are in parallel, across the inside terminals of the repeating coil windings w, y. Current can then flow through and operate the line relay $L R$.

If the operator desires to ring bell A, she inserts the plug in the jack and closes the ringing key $A k$, and alternating current flows from the ringing generator G through c–t–t'–l–C_2–$A R$–e–g, closes relay $A R$ ($A R$ and $D R$ being so constructed as to be readily operated by alternating current), thereby allowing the alternating ringing current to flow from the same ringing generator G' through i–A–f–h–G' and ring the bell A. If D is desired, the key $D k$ is closed, thereby closing the relay $D R$ and ringing the bell D in a similar manner.

64. Subdivision of Long Four-Party Line by Repeating Coil.—To provide four-party selective ringing with pulsating currents, it is necessary to eliminate the condensers, because a pulsating current in one direction only cannot be satisfactorily transmitted through them. If a 500-ohm relay shunted by non-inductive resistance of 100 or 200 ohms is inserted in each side of the line circuit, the transmission will not be appreciably affected, and the shunted 500-ohm relays can be made sufficiently sensitive to operate on any resistance below 3,000 ohms. Such a circuit is shown in Fig. 22, in which an impedance coil of 750 ohms resistance is arranged to be bridged across the line wires only when both the relays R, R' are closed. This circuit interposes nothing to prevent selective ringing. A positive or negative pulsating current over the upper wire only, returning through A, M, and the ground, will operate relay R only; and,

similarly, a positive or negative pulsating current over the lower wire only, returning through *D*, *N*, and the ground, will operate only relay *R′*. Hence, in either case, one of the two relays will remain open and the 750-ohm coil will not be bridged across the line circuit while ringing. If any subscriber takes down his receiver, thereby bridging his talking circuit across the line wires, enough current will flow from *B* to close both relays *R*, *R′*, thus bridging across the line wires the impedance coil *r* through which enough current can flow to operate the regular line relay *L R*. The 750-ohm impedance coil now bridged across the line circuit will not appreciably affect the transmission of voice currents.

EXCHANGE WIRING AND EXTENSION TELEPHONES

THE WIRING OF EXCHANGES

1. Importance of Systematic Wiring.—All the wiring of switchboards should be systematically and neatly done, especially in large exchanges, for unless the wires are systematically arranged, the confusion will be so great as to render testing a very difficult matter, besides giving the entire work a very unsightly appearance. A still more important reason is the fact that space must be economized to the last degree. Where a group of wires leads from one portion of a switchboard frame to another, as, for instance, from the jack-terminals to the drop terminals, it is customary to bunch the wires into cables, which are especially formed with a view to being adapted to the particular conditions in which they are to be used. These cables are usually composed of No. 22 or 24 B. & S. tinned copper wire, which may have a covering like the ordinary annunciator wire, but it is far better to use a covering composed of one, or preferably two, wraps of silk, outside of which is a single wrapping of cotton. The size of the conductor is limited on one hand by current-carrying capacity, and on the other hand by necessary mechanical strength. Some circuits might require a low-resistance conductor in order to properly work the signal system, so that a copper wire as large as No. 18 B. & S. might be necessary, while other systems with circuits, not limited in their proper and efficient working to low resistance of the exchange wiring, can use much smaller conductors, in which case mechanical strength is a limiting factor. Thus, a No. 24 B. & S. copper

wire might come within the allowable limits. The smaller the wire used, the smaller is the space occupied by the cables, and the advantages thus gained must be taken into consideration with the items, carrying capacity and mechanical strength.

The wire is tinned in order that it may readily take solder, and as it may be necessary to solder it at any portion throughout its length, the expense of tinning the whole surface of the wire before it is insulated is a small matter in comparison with the increased ease of working with it secured thereby. The Bell Companies use a tinned copper wire insulated with two wraps of wool, and outside of that a braiding of wool. Wool will not burn, at least not with a flame, and for this reason the wire is called flame-proof.

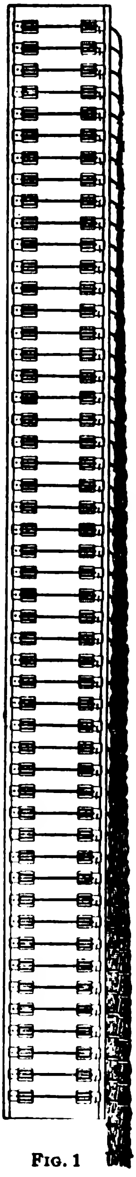


Fig. 1

2. All talking circuits should be metallic in an exchange, no matter whether metallic, common-return, or ground-return systems are used for the outside work; they must be run with twisted-pair wire, thus keeping each exchange circuit transposed in respect to all others for its entire length. This will effectually prevent cross-talk or other inductive disturbances, provided that there is no unbalancing due to other sources, such as placing apparatus in one side of the circuit and not balancing the other side. Twisted pairs are usually provided with a plain (white) covered conductor for the tip of line or circuit and a color code wire for the sleeve of the same circuit. Six twists per foot have been found to give good results for both flexibility and balance of circuit. The conductors are usually laid spirally in the cable to give flexibility. Increasing the number of turns per foot makes the cable more flexible, but at the same time increases its diameter.

FORMING CABLES

3. The matter of properly forming a cable is one that requires some skill and often ingenuity; and the performance of the work may be greatly facilitated by carefully planning it beforehand. Short runs or local wiring, which require a rather complicated layout and many kinds of conductors, are

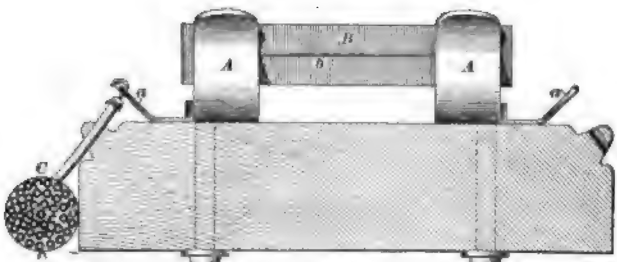


FIG. 2

made over special forms by hand, and are known as **hand-made cables**, while all long runs between the apparatus frames, and between the frames and switchboard, are usually run with what is called a **machine-, or ready-, made cable.**

One of the simplest cables to form is shown in Fig. 1, where it leads from a lightning-arrester strip having all its terminals arranged in a single row. In order to render the description clearer, a transverse section of this strip, showing, in elevation, the terminals and fuse, is given in Fig. 2, while in Fig. 3 is given a side elevation of a portion of Fig. 1, showing an end view of one of the clips. In these, A, A are a pair of clips arranged on opposite sides of the terminal strip, adapted to hold a mica fuse strip B that

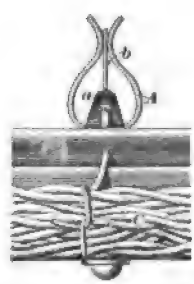


FIG. 3

carries a fuse b secured to it with shellac. The connection between the two clips A, A is thus made complete through the fine fuse wire b, when the latter is intact. A lug a is formed from the same piece of sheet metal as A, and bent up at an angle of about 45° to the plane of the terminal strip, in order

to form a convenient means for connecting the wires of the cable. A section of the cable is shown at *C*, one of the wires being led therefrom through a hole in the wooden strip to the lug *a*, to which it is secured by a drop of solder. The strip shown in Fig. 1 has terminals on each side for fifty wires, or twenty-five pair of wires, and in forming the cable the object is to bring out the various pairs of wires at points corresponding to the position of the terminals, so that when the cable is laid alongside of the wooden strip each of the various wires will come opposite its proper terminal, to which it may be secured, as already stated.

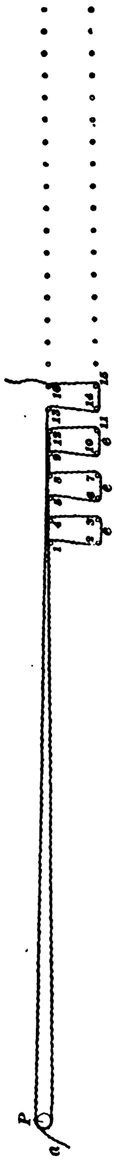


FIG. 4

4. Directions for Laying Out Cable. The method of procedure in laying out a cable is outlined in Fig. 4. Two rows of nails *1, 2, 3, 4* are driven in a board, the distance between the adjacent nails in the same row corresponding to the distance between the pairs of terminals on the terminal strip to which the cable is to be attached. The distance between the rows is made about equal to the length that it is desired to have the individual wires project laterally from the cable. No. 14, $1\frac{1}{2}$-inch wire brads with small heads—or, better, with no heads at all—will be found most suitable for this work. Having determined the extreme length of the cable, which we will say is 6 feet, a wooden pin or heavy screw *P* is driven in the board at a little greater distance than 6 feet from the nails at the outer end of the row. The spool containing the twisted pair of wires is mounted in some convenient place upon a spindle so as to revolve easily. The end *a* of the twisted pair is then attached to the pin *P*, and the wire is led around nails *1, 2, 3*, and *4* and back to the pin *P*,

being kept under moderate tension all the time. It is then passed around the pin and led back to nail *5* and around nails *6*, *7*, and *8* and again back to the pin *P*. This process is repeated until all the nails have been engaged, the wire being continuous throughout its length. If a break should be found in the wire, it should not be spliced, but a new beginning made at the pin *P*, as at that point all wires will eventually be cut. As the cable is to have twenty-five pair, there will be twenty-five nails in each row, each nail serving to bring out a single pair from the cable.

5. Lacing or Sewing.—After the wire is properly laid, it should be laced or sewed in the form of a cable before it is removed from the nails. To do this, a stout linen thread or twine, similar to that used by shoemakers, but heavier, is passed once around the cable, near the pin *P*, and tied by an ordinary square knot *b*, Fig. 5. The thread is then led in the direction of the wires about $\frac{3}{4}$ inch, when it is again passed around the cable and over and then under itself, after which it is pulled up tight, forming what is known as the **lock-stitch** *c*. The method of passing the thread in forming the stitch is illustrated at *d*. The linen thread should be thoroughly waxed before it is used; but that known as Barbour's linen thread is much used because it requires no waxing and has great strength.

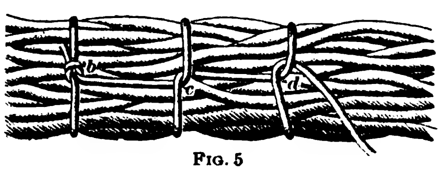


Fig. 5

6. Wrong Method of Lacing.—In Fig. 6 is shown the wrong method of making this stitch that a beginner is very apt to use unless specially cautioned against it. It has the disadvantage that the part of the thread which lies parallel to the cable does not lie close to the wires, as in the method shown in

Fig. 6

Fig. 5, and also that a considerable length of thread will unravel if it is broken at any point.

7. Cutting Loose.—The stitch should be repeated at regular intervals throughout the length of the cable. When the first nail *1* is reached, the stitch should be taken just at the point where the wire is led around it, as shown in Fig. 7, so as to include that wire under the stitch. The next stitch should be taken just at the second nail, where the second pair is led off, and so on, the process being repeated at every nail in the row nearest to the cable. After the cable

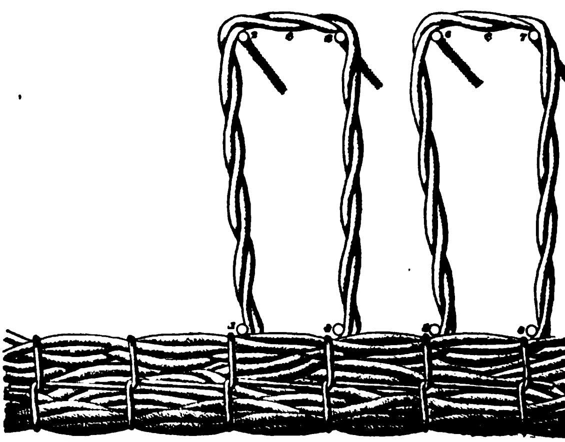


FIG. 7

is laced, all the wires should be cut at the pin *P* and also at each of the points marked *e* in Figs. 4 and 7. This renders the cable complete, it being readily seen that there are now twenty-five pair of wires running through it, the pairs being brought out from the cable at intervals corresponding to the terminals on the terminal strip. The end at the pin *P* was not formed in this case, but it usually happens that both ends of the cable can be formed at once where needed, in the same manner as in the right-hand end of Fig. 4. The proper spacing of the nails is, of course, a matter that must be determined in each case by the existing conditions.

8. Bends in Cables.—In case the cable must, when in place, have one or more sharp bends in it, it is far better to form the cable with the bends at the proper places, as in this way a clean, square turn can be made, which cannot be done by bending a large straight cable after forming. Any number of sharp bends may be made in a cable while it is being formed, by carrying the wires around pins placed at proper points in the forming board.

The cable should be thoroughly insulated with a wrapping of cohesive tape at such points as may come in contact with any iron framework.

9. Soldering to Terminals.—After the cable has been cut loose from the forming board, the ends of the various wires should be "skinned" for a distance of about ½ inch, in order to permit of soldering to the terminals. The terminals are usually provided with a small hole in their ends, through which the wires should be run before soldering. It is best, in connecting up a cable having a large number of terminals, to place all the wire ends in their proper positions before soldering. The wire should in each case be bent back on itself after passing through the hole in the terminal, in order to secure it in place. After all the wires are in position, they may be very rapidly soldered by the use of a soldering iron. As before stated, no acid should be used in this process, on account of its liability to corrode the terminals. This is of especial importance in switchboard work.

10. Fastenings for Cables.—It is usually necessary to secure the cable in position against the framework of the switchboard or other structure; the best way to do this is by the use of short rawhide straps, the ends of which are held against the woodwork by round-head wood screws passing through small copper washers, as shown in Fig. 8. A very neat appearance may be given to the work by giving the cable a coat of good shellac after it is in place and all the connections made.

FIG. 8

It is sometimes more desirable to do this before the cable is put in place in the switchboard. This coating of shellac, besides improving the appearance, renders the adhering of dust to the cable less liable to happen, and at the same time stiffens the cable, thus making it hold its form better.

11. Ready-Made Cables.—Where long cables are necessary in switchboard work, as, for instance, from the switchboard terminals to the distributing terminals, it is a very tedious matter to form up a cable by the methods described, and better results can be obtained by using a cable already manufactured. In fact, all cables, as far as possible, should be machine made, having conductors of tinned copper wire, not smaller than No. 24 B. & S., with an inside wrapping of silk and an outside wrapping of cotton and twisted in pairs or triplets as required. This may be procured in various forms and according to almost any specifications required. Cables of this kind are usually covered with several wrappings or braidings of cotton or linen, the outside one often being impregnated with a fireproof or slow-burning paint. A covering recommended consists of two or more reversed wrappings of Manila-paper tape and an outer cotton braiding, the latter being either saturated with hot beeswax and polished or provided with a coat of lead paint. It is desirable that the inner covering of the cable shall be a wrapping instead of a braiding, as in "skinning" the cable the outer braiding may be cut with a sharp knife without approaching too near the conductors themselves. The inner covering, if it is a wrapping, may be readily removed by unwinding, while if it is a braiding it must also be cut, and it is difficult to do this without injuring the wires. Cables of this kind are treated in practically the same manner as cables that are formed by hand. The ends, after having been skinned, may be shaped around pegs or nails in order to make them conform to any desired set of terminals. The two conductors in machine-made cables are usually given about one and one-half twists per foot.

12. Identifying Wires.—In ready-made cables, no means were formerly provided for identifying the wires at the ends. In this case, the only recourse is to test them out with a magneto-bell, or receiver and battery, which in the case of rather large cables is a very tedious operation, especially where a great number of cables are used. To obviate this difficulty, what are known as circus cables have been devised and are largely used, especially in multiple-switchboard work. In these, the different pairs of wires are provided with a covering of some distinguishing color, so that the two ends of the same wire may be at once picked out by sight without recourse to testing.

EXCHANGE PROTECTIVE DEVICES

13. Lightning arresters, heat coils, and **fuses** have been quite fully explained in connection with substation protective devices, hence it will only be necessary to show here their application in the exchange. A complete protector for telephone lines includes three forms of protective apparatus: First, an open-space cut-out, designed to act as a spark gap and relieve the circuit from high potential discharges by forming a non-inductive path to ground. Second, a thermal apparatus so designed that when an abnormal current of relatively low voltage appears the thermal apparatus under the effect of the heat created by the extra current will operate in such a manner as to open or ground the side of the circuit toward the apparatus to be protected and ground on the other, or line, side. The third form is a fusible cut-out of relatively large current-carrying capacity and extended across a long gap.

These three pieces of apparatus are known by the names of the open-space cut-out lightning arrester, or static arrester, the heat coil, or sneak-current protector, and the fuse. For the complete protection of a telephone line it is usually considered desirable to place an open-space cut-out and heat coil on the distributing board to protect the central-station apparatus, to place a fuse wire on underground lines where

the cable to the central office joins open wire, to place a second fuse and open-space cut-out and sometimes a heat coil at the subscriber's telephone substation.

Each line wire terminating in a large exchange installed in London in 1906 by the Western Electric Company was equipped with carbon arresters, heat coils, and long tubular fuses. Each cord circuit was also provided with separate fuses located in the power room, the connections to the fuse board being made through lead-covered cables.

14. Fig. 9 shows the relations of one line wire to the three elements of a protective apparatus. Whenever the three elements—fuse, static arrester, and heat coil—are used, the relation of the elements should be as shown in this figure. The first duty of protective apparatus is to prevent foreign currents from damaging central-office equipments; hence, the proper position for the fuse is between that part of the line circuit that can come in contact with a source of dangerous current and the office equipment. The term *exposed wiring* may be applied to such parts of the line as may ever come in contact with a source of dangerous current, while the term *unexposed wiring* may be applied to all parts of the line that are secure from such contact. Unexposed wiring includes underground cables, cables formed of wires insulated with rubber, and wiring wholly within buildings. All other wiring may be considered as exposed to accidental contact with high-potential circuits.

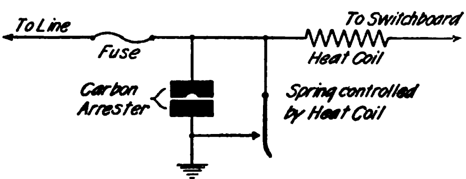


FIG. 9

In this class aerial cables having lead sheaths are included, because contact between such a cable and a high-potential wire very frequently causes an arc that destroys the sheath, and allows current to enter the conductors. The results are consequently as serious as if the lines within the cables were open wires. The proper position of the fuse is at or near

the point of junction between exposed and unexposed wires; hence, where the line enters a central office through underground cables the fuse should be located at the outer ends of these cables, as that is the junction between the exposed aerial distributing wires and the unexposed underground wires. If the lines enter the office, however, by means of aerial cables, the fuse should be placed at the central-office end of these cables, as that is the junction between the exposed wires of the aerial cables and the unexposed wires at the central office. A fuse should also be placed between exposed outside wiring and a subscriber's telephone instrument.

15. Some companies have abandoned the fuse at the outer end of underground cables and have placed it in the office. But, it is doubtful if this is good practice; for, with the grounding of the circuit by the carbon arrester or the heat coil and the melting of the fuse, the line is left open and all the strain is placed upon the cable insulation. Should the voltage be high or the cable have any weak points, a very bad burn-out may result and place all the lines in the cable in trouble.

As the weakest point is in the wiring of the cable pole, a disastrous fire is very likely to take place at that point. The fuses should be made and located so that when they blow the arc cannot be communicated to the adjacent fuses or in any way cause a fire. There are fuse protectors so arranged that the blowing of a fuse will set fire to all those above it, and even to the cable box. It is, of course, hard to design a cable box so that a fire can never result, but a reasonable amount of care will give fairly good results. All fuse mountings should be fireproof, either iron, porcelain, or glass.

16. Relation of Carbon Arrester and Heat Coils. There are three ways in which carbon or open-space cut-outs and heat coils may be associated with other parts of the central-office equipment: first, on the iron cable heads in which the cables terminate; second, on the side of the main

distributing frame to which the incoming lines immediately connect; and third, on the switchboard side of the main distributing frame. Except for special reasons, the iron cable heads with arresters on them are not now much used. The advantage of placing the arresters on the line side of the main frame is that as the lines are ordinarily tested from the arrester frame, such a location enables the test to include no part of the central-office wire, but to be applied immediately to the outgoing-cable conductors. The advantage of placing arresters on the switchboard side of the main frame is that the full number of arresters will then be no greater than the number of lines in the switchboard. Since the number of lines entering the central office may be from 20 to 50 per cent. greater than the number in the switchboard, the arrester equipment is naturally much less in the latter case. There are usually about 30 per cent. more line wires than switchboard line circuits. The advantage of more refined testing facilities must be considered, therefore, against the advantage of lower first cost of equipment. By far the greater number of modern central offices have the arresters on the switchboard side of the main frame.

17. In all cases of lightning discharges, the carbon arresters at either end of a line are not sufficient. For instance, on long wires it is sometimes necessary to place an additional carbon arrester at a point near the junction of the open wire and the cables. As far as lightning alone is concerned, this method is effectual, but unfortunately a new hazard is introduced, due to the fact that a separation between the carbon blocks small enough to protect the cables against damage from a discharge, is also a separation small enough for an arc to be produced by an accidental contact with a circuit whose potential is about 1,000 volts. If such a contact is made and an arc is started between the carbon blocks, it may be maintained until the blocks are destroyed by the arc, and a fire may be the result. In such cases a fuse should be inserted in the line toward the open-wire portion. A separation of .01 inch is a practical one between the carbons used at the

end of the cable. This separation reduces the probability of starting an arc at the outside arrester, and throws the burden of grounding where it belongs, that is, upon the carbon arrester in the central office, whose air gap is about .005 inch. There is a tendency to higher and higher voltage transmission systems, and it is probable that developments will be made that may cause a revision of the telephone protective system.

18. Disturbances in telephones due to a wireless-telegraph station in the neighborhood may usually be eliminated by connecting a condenser of small capacity, from .002 to .005 microfarad, around the air gap of each pair of carbon arresters, that is, from each line wire to ground. This will allow the very high-frequency static charges, produced by the wireless-telegraph station when sending messages, to readily pass to the ground through the condensers whose capacities are too small to appreciably affect the transmission of telephone currents.

19. Let us consider a system having underground cable from the exchange to the edge of the business district, then overhead cable for a distance, and finally bare overhead wire to the telephone station. Complete protection for such a line will be arranged as follows: From the switchboard the circuit passes through the heat coil, carbon arrester, underground cable, long enclosed fuse in cable box, overhead cable, carbon arrester and fuse in cable box, bare overhead wire, fuse and carbon arrester at the telephone station. The carbon arrester at the junction between the overhead cable and bare wire seems advisable only when the bare line is long. If it is used, the separation between carbons will be about .01 inch, while at the exchange the separation will be only .005 inch, in order to avoid too frequent interruption of service by the useless operation of the outside arrester. The station arrester can be readily attended to while protection outside the exchange is always liable to be a source of expense to maintain and repair and an interruption to service.

Where the overhead cable is in no danger of becoming crossed with a light, power, or high-potential circuit, it does

not seem necessary to use a fuse between an overhead cable and an underground cable; the fuse between the overhead cable and bare wire should be sufficient.

20. For a city telephone system in which the only exposed overhead wire is a short drop line from the distributing pole to the house, the protecting apparatus should be arranged in the following order: Starting at the exchange, each circuit should pass through a heat coil, a lightning arrester, lead cable, terminal box, drop wire to wall of house, line fuse where drop wire enters the house, interior wires to telephone.

It is not advisable to overdo the matter of protection, because it means increased first cost and cost for maintenance and annoyance due to interruptions of service. It may be preferable to have a bell coil burned out occasionally rather than to have too elaborate a system of protection at the telephone stations.

HEAT COILS

21. The heat coil at the exchange may be arranged to open or ground the switchboard side of the circuit when it operates; in central-energy systems it seems preferable to ground the switchboard side, provided that this does not short-circuit the common battery, as the line signal will then be displayed and the operator, being unable to get a reply, will report the line in trouble. It is usually arranged to ground the line side of the circuit of any system when it operates. Thus it may ground both the line and switchboard circuits, or ground the former and open the latter. A small current, usually less than 1 ampere, that flows into a telephone circuit on account of a cross between the telephone line and some power, lighting, or other foreign circuit is termed a **sneak current.** Heat coils are designed to be operated by these sneak currents if they continue to flow for a certain length of time, usually about 30 to 45 seconds.

22. A heat coil for use in a local-battery (or magneto) system that is wound to a resistance of 41.5 ohms with

36 inches of No. 37 B. & S. double silk-covered German-silver wire so as to be operated in less than 45 seconds by .16 ampere, would be wound to a resistance of 5.25 ohms with 23 inches of No. 30 B. & S. German-silver wire, so as to be operated in less than 60 seconds by .4 ampere when used in a common-battery system. This is done because the coils used in common-battery systems are usually able to carry, without injury, a larger current for a longer time.

An ordinary specification for a switchboard heat coil is that it shall carry .1 ampere indefinitely and operate on .2 ampere within 5 minutes, the coil being wound to about 20 ohms. A specification that is now more common requires the heat coil to stand .2 ampere indefinitely and to operate on .25 ampere within 3 minutes, the coil being wound to about 7 ohms.

One manufacturer considers that all telephone apparatus should be constructed to stand .3 ampere indefinitely and that heat coils should operate on .35 ampere within 2 minutes, and have a resistance not exceeding 5 ohms. All heat coils should be non-inductively wound.

23. Taylor Sneak-Current Protector.—Wm. A. Taylor has patented, for the Kellogg Switchboard and Supply Company, a protective device in which the ordinary heat coil is replaced by a special conductor of high resistance, such as a specially prepared carbon. The carbon is made in the shape of a short cylinder, or rod, the flat ends being secured to copper terminals by a solder that melts at the desired temperature. The high-resistance carbon becomes heated by the passage of an abnormally large current, this melts the solder and allows one of the terminals, under the action of a spring, to fly off, thus opening one side of the circuit, and, if desirable, grounding the other side and ringing an alarm bell. This current protector can be used in exactly the same manner, and in the same protective devices, in which heat coils are generally used. The difficulty in obtaining or making a carbon uniform in resistance is the disadvantage of this device, and judging by its limited use it has not proved very successful.

FUSES

24. The fuse protector, Fig. 10, consists of a hollow cylinder of enameled wood or fiber about 4 inches long and ½ inch in diameter, to the ends of which are secured metal terminals. The fuse, the ends of which are fastened to the metal terminals, is inside the tube, which prevents the scattering of the melted metal. The tube may be hermetically sealed, which protects the fuse from air-currents and makes it operate more uniformly by the current for which it was designed to melt. For cable terminals at a distance from the exchange, the fuse is made so as to be melted by a current of 8 amperes, and at the central exchange by a current of 3 to 5 amperes. Currents smaller than this are taken care of by the protecting devices at the central station and at the subscriber's telephone.

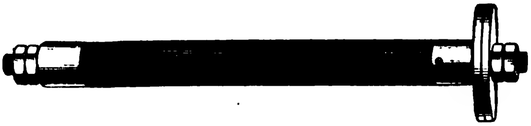


FIG. 10

The tubular fuse shown in Fig. 10 is designed to be clamped directly on the line wire at the insulator, and the bridle wire to be connected to the other end of the fuse, the fuse serving as a means to connect the bridle to the line wire. Long fuses of this character are made with terminals suitable for most any purpose and are extensively used by most companies. The fuse strip is sometimes surrounded with gypsum, asbestos, or other fire-resisting material inside the tube.

25. Experience seems to show that on common-battery systems, a 5- to 7-ampere fuse should be used to protect the cable wire; while for magneto-systems it is customary to use from 3- to 5-ampere fuses, because, as there is no battery connected to the line, a more sensitive fuse can be used, without too much trouble from accidental interruptions.

COMPLETE EXCHANGE PROTECTORS

26. In Fig. 11 is shown the protective devices for one pair of line wires as used in many Bell exchanges. The protective device, including a heat coil *A* and pair of carbon lightning arresters *H*, *H'* for each side of each line wire, are attached to the frame of the main distributing board. For magneto-exchanges, the heat coil is frequently wound with 34.5 inches of No. 37 B. & S. German-silver wire wrapped about a small metal plug *a*, which is held in its place by a drop of solder of such composition that it will fuse at a very low temperature. The passage of a very small amount of current, about .3 ampere for 30 seconds, through the coil will cause the solder to melt, and thus release the pin *a*. The resistance of this coil is about 28 ohms. Heat coils vary in resistance from about 3.6 to 50 ohms, depending on the circuits they are used to protect. The heat coil is protected by the hollow cylinder *A* of fiber or hard rubber. The heat coils are normally held between two springs *m* and *l* and *n* and *l'*, as shown. The pin *a* projects through a slot in the spring *l* and rests against a small flexible spring *c* riveted to the spring *l*. To the spring *l* is attached the line wire *l*, while to the spring *m* is attached the wire *m'* leading to the switchboard through the cable *S*. As the heat coil is included in the circuit between these two springs, it follows that whatever current passes over the line wire must pass through the small German-silver coil inside of *A*. The

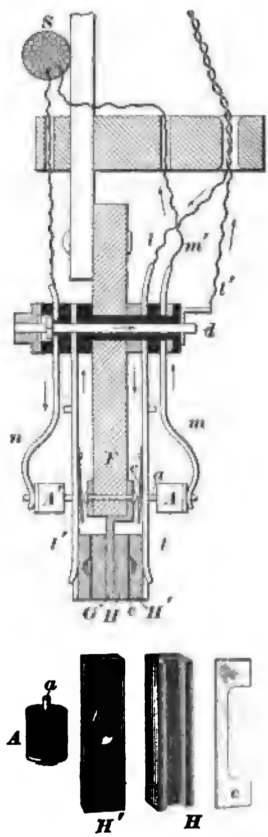


Fig. 11

plate *G* is grounded, and on it rests the carbon block *H*; the other carbon block *H'* of the pair rests under the spring *l*,. and the two blocks are held apart from $\frac{1}{100}$ to $\frac{1}{200}$ inch by a thin strip of mica *e*.

27. An additional precaution is provided by enclosing in a slight depression in one of the blocks a drop *h* of fusible metal that melts at about 160° F., so arranged that it will not touch the other block of the pair when the mica strip is between them.

G. W. Pichard devised (patent No. 807,962) for the Bell Company an improvement in the manufacture of carbons. It consists in immersing the carbon blocks for 30 minutes in a solution of 1.4 pounds of resin, which acts as a binding material, to 4 gallons of turpentine at a temperature of from 150° to 160° F. The blocks after being drained and dried in air at a temperature of from 150° to 160° F. for 24 hours are ground to leave a rough surface. It is claimed that blocks so treated do not leave carbon dust after a discharge. It is this dust that causes much of the trouble with carbon arresters.

28. The **operation** of this device is as follows: If a current caused by a high potential, 300 volts or over, comes in over the line *l*, it will pass by spring *l* to the carbon block *H'*, and will jump across the air-gap to the block *H* and to ground. If the discharge is of sufficient duration, the fusible alloy in block *H'* will be melted, thus completely grounding the line. If a sneak current comes in over the line, it will pass from the spring *l* through the heat coil to the spring *m* and through the switchboard drop. After a very short interval of time, the heat developed in the coil will melt the solder, thus releasing the pin and allowing the spring *m* to force the pin *a* through the coil, and this pin presses the small spring *c* into engagement with the ground plate *G*. This throws a dead ground on the line, and at the same time the spring *m* makes contact with the spring *l*, thus short-circuiting the switchboard apparatus. The arrester mounted on the other side of the strip *F* forms the protection

for the other side of the same line circuit. The line wire l' is connected with the spring l' through the bolt d passing through the strip. This bolt makes connection only with the spring l', which is the mate to the spring l on the other side of the strip. The heat coil A' is connected in an exactly similar manner between the springs l' and n. The operation of the arrester on this side of strip F is precisely the same as that on the other side. The arrows show the path of the telephone current under normal conditions.

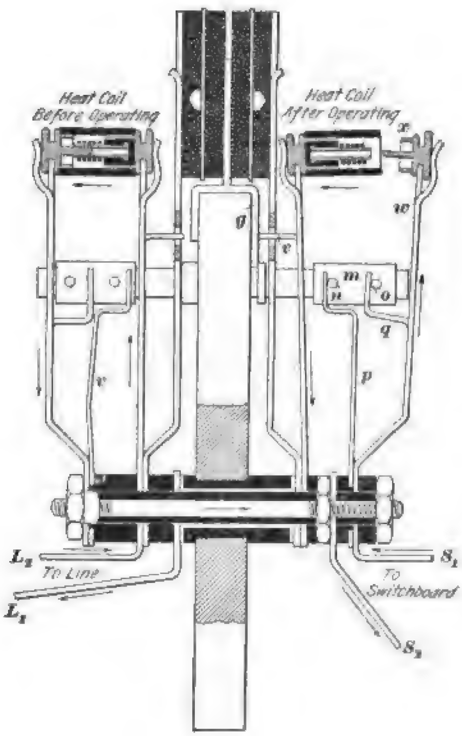


FIG. 12

29. Sterling Protector.—A terminal protector made by the Sterling Electric Company is shown in Fig. 12 in such a clear manner that no explanation seems necessary. The construction of the heat coil and the position of the springs before and after operating are clearly shown. The arrows indicate the path of the telephone currents when both sides are set. In the hard-rubber or wooden piece m are two metal pins n, o.

When an excessive current warms the heat coil, a fusible solder is softened, thereby allowing the spring w to pull the end piece x out of the coil, thus opening the switchboard side S_1 of the circuit and grounding the

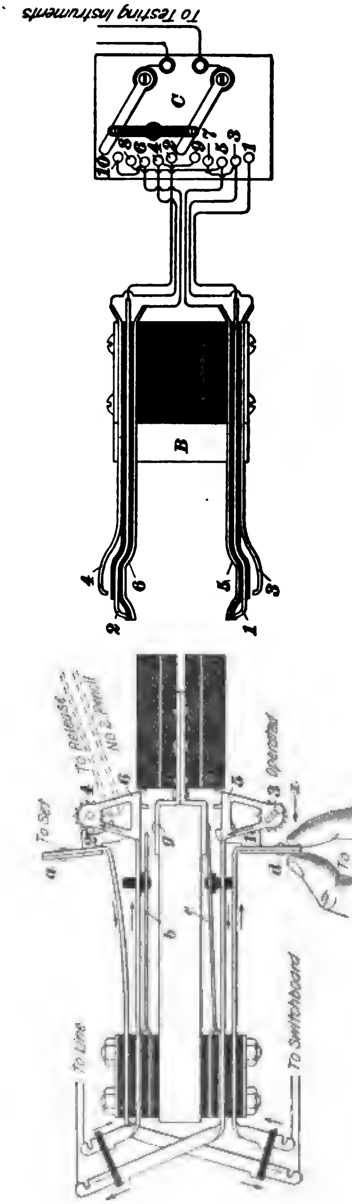


Fig. 13 (a)

line side L_1, because the contact finger v now touches the ground plate g.

30. Cook Protector. The No. 8 self-soldering heat-coil, lightning protector, and test plug made by Frank B. Cook is shown in Fig. 13 (*a*). This protector has four spring contacts normally in series in the line circuit for each pair of protectors, and two of these have two points of bearing each. To restore the coils to their normal position after operation, it is necessary only to press the circuit controlling spring d in the direction of the arrow x. The coils themselves do not have to be removed or replaced. All the parts are mounted on a heavy metal bar, which is intended to be permanently connected to earth. No bolt or soldered connections are required to make the two line and two switchboard terminals come out on the same side. Thus danger of a poor connection or a leakage to ground through such bolts or soldered connections is eliminated.

31. The heat coil, shown in **Fig.** 13 (*b*),

comprises a metal pin *f*, soldered by an easily fusible solder to a metal spool *e*, upon which is wound several inches of silk-insulated resistance wire *w*. An abnórmal current passing through this wire heats the spool and melts the solder. The thickness of the insulation separating the wire from the spool is only about .002 inch. The metal shell that encases the coil proper is formed over at both ends, completely encasing the fusible solder. This protector opens the switchboard circuit at springs *a*, *d*, and grounds the line circuit through springs *b*, *e*.

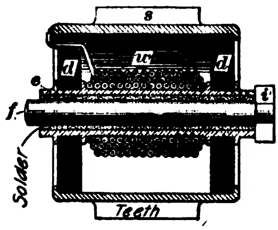


FIG. 13 (*b*)

32. Operation.—When an abnormally large current passes through the heat coil, the tension of the spring *a* causes the metal cylinder to revolve and the spring slips from the position shown at *2* into the position shown at *1*; spring *e* then touches the ground strip *g*. A pair of pincers is provided suitably shaped for conveniently removing and inserting the heat coils in position. By inserting an ordinary lead pencil, as shown, on one side, the heat coil is easily released and the springs may be set again by grasping one end of the spring *d* between the thumb and finger and pulling sidewise in the direction indicated by the arrow *x*.

One of the carbon lightning arresters is normally connected to the line and separated from the grounded carbon by mica not less than .005 inch thick. A potential of more than 350 volts is required to arc across this space. As an added protection, the carbon arrester always remains in contact with the line.

33. The **test plug** *B*, Fig. 13, is connected by a six-wire flexible cord or cable with a switch for the use of the wire chief. After pushing the test plug into position so as to make contact with the springs of the protector, the wire chief may test the switchboard circuit by placing the switch *C* on terminals *1*, *2*, and may test the line through the heat coils, by placing the switch on terminals *3*, *4*; the line

without heat coils, by placing the switch on terminals *5*, *6*; one heat coil alone, by placing the switch on terminals *7*, *8*; and the other heat coil, by placing the switch on terminals *9*, *10*. Pushing the plug into its position on the protector causes like numbered springs to make contact, at the same time separating springs *1*, *2* on the terminal from the contact with the outside surfaces *3*, *4* of the heat coils.

34. Kaisling Protector.—In Fig. 14 is shown the **Kaisling protector** made by the American Electric Fuse Company. An excessive current through the heat coil, which is self-soldering, softens a solder that holds the pin *c* in place and the spring *e* pushes the pin through the coil so that it pushes the spring *d* away from spring *a* and against the grounded piece *g*. Thus the line spring L_1 is grounded and the switchboard side of the circuit is opened at spring *a*. In the operated position of the heat coil, the pin *c* connects the alarm spring *e* to the spring *d* and through it to the grounded piece *g*. The operation of the coil does not harm it. When the operating current ceases, the pin *c* cools and becomes resoldered; to restore the protector to normal condition, it is only necessary to remove the heat coil, turn it end for end, and insert it in position again.

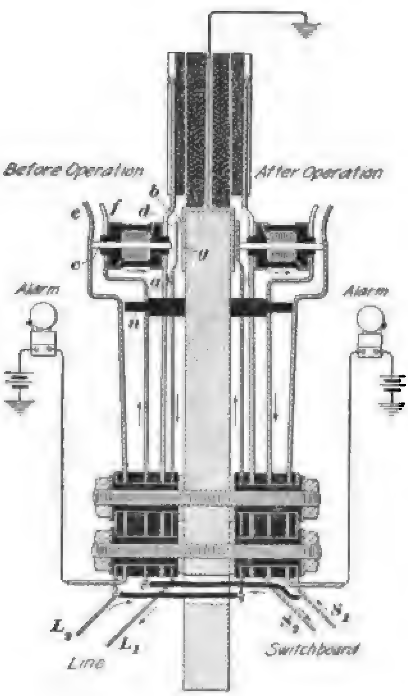


FIG. 14

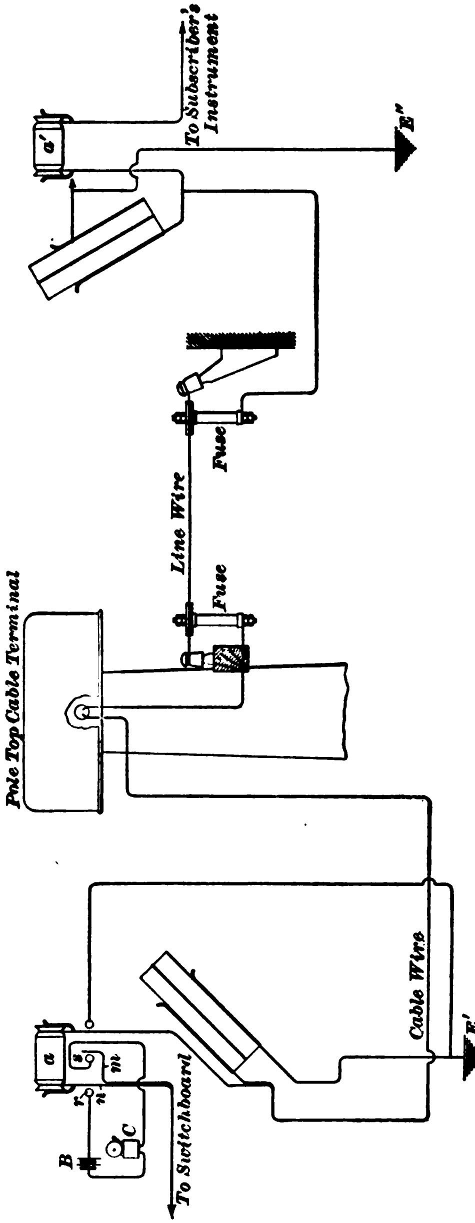

To Subscriber's Instrument
a'
E''
Fuse
Line Wire
Fuse
Pole Top Cable Terminal
Cable Wire
E'
a
s
m
r
n
C
B
To Switchboard

FIG. 15

The fiber insulating pin *n* prevents the spring *e* from touching *f* even when the heat coil is removed. Platinum contacts are used between springs *a*, *d*, which is an excellent feature. A testing plug is made for this protector.

35. When protectors are located at the central exchange, a signaling device is often used to notify the attendant by the ringing of a bell when a line becomes grounded. This is shown at the left-hand side of Fig. 15, where the circuit of the local battery *B* and bell *C* is closed when the springs *n* and *m* make contact with the pins *r* and *s*, respectively. This represents the Sterling type of protector. For station use, the carbons are usually separated by a perforated piece of mica .005 inch thick.

Fig. 15 shows the complete method of protecting the telephone at one end, the station apparatus at the other end, and the line fuses for protecting the cable from excessive currents caused by crosses between the overhead telephone and electric light or power lines. One fuse is connected between the cable and the overhead line wire and another between the overhead line wire and the subscriber's telephone. It is not generally considered necessary or advisable to use heat coils in addition to carbon arresters and fuses at the subscriber's end of the line; long enclosed fuses and carbon arresters or heat coils and carbon arresters are usually sufficient, the first two being preferred.

DISTRIBUTING BOARDS

36. Desirability.—A very important feature in telephone exchanges, whether large or small, is the **distributing board,** or **frame,** by which various changes necessary in the arrangement of the line circuits with respect to the switchboard terminals may be made without disarranging the switchboard or line cables. Small exchanges are frequently constructed without a distributing board, but this is usually due to ignorance of the advantages to be derived from such a board rather than due to a lack of funds, for a distributing board for a small exchange may be constructed at a very small expense and with very little trouble.

SMALL DISTRIBUTING BOARDS

37. Design and Construction.—For an exchange having fifty subscribers or less, a very convenient distributing board may be made as shown in Fig. 16. *A* is a well-seasoned pine board 8 inches wide and long enough to accommodate as many terminals in one row as there are wires to be led to the switchboard. *B* is a lightning-arrester strip containing the requisite number of fuse clips of the general form shown in Fig. 2, or preferably of such size and form as to hold the long enclosed fuses. It is sometimes desirable that carbon blocks should also be used, and where this is the case, porcelain blocks carrying the complete arresters may be mounted side by side on the board *A* instead of the extra wooden strip *B*. This strip of arresters should be mounted about $1\frac{1}{4}$ inches from the lower edge of the board, as shown. On the same side of the board and about the same distance from the upper edge should be mounted a strip of pine *C* of the same length as the lightning-arrester strip and 1 inch square. The two edges of this should be beveled, as shown in the sectional view. On this strip is mounted a number of

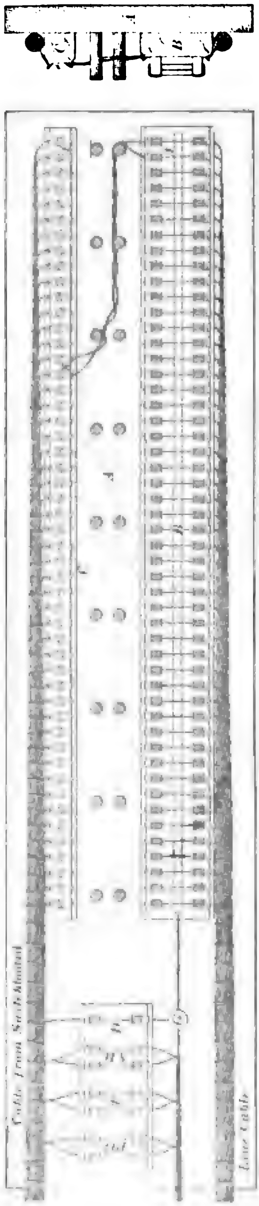


Fig. 16

connectors corresponding to the number of terminals on one side of the board *B*. Between the strips *C* and *B*, two rows of ⅜-inch holes are bored in the board, these holes being placed at convenient intervals about opposite the center of every third pair of connectors. Into these holes are driven round wooden pins, long enough to project 1½ inches from the face of the board. The strip *B* is for the wires leading from the subscribers' stations, while the strip *C* carries terminals for the corresponding wires leading from the switchboard.

38. Connecting Line and Switchboard Wires.—The line wires are formed into a cable, which is fanned out according to the method shown in Fig. 1, and the various terminals are permanently soldered to the lightning-arrester clips. In a similar manner, the wires leading from the switchboard are formed into a cable and fanned out to the terminals on the strip *C*, Fig. 16, to which they are permanently soldered. A gap now exists between each line wire and the wire leading to the switchboard, and this gap is bridged across by what are called **jumper wires**, extending from the lower terminals of the connectors on the strip *C* to the upper terminals of the arresters on the strip *B*. Inasmuch as the pair of wires terminating in

clips *1* on the strip *B* will in all probability *not* be connected to the *1* pair of connectors on the strip *C*, the jumper wire will not extend straight across from strip *B* to strip *C*, but will be led around the various wooden pins in a manner indicated in the figure from *1* on strip *B* to *8* on strip *C*.

The jumper wire for both main and intermediate frames should be composed of No. 20 or 22 tinned flame-proof wool-covered, or preferably rubber-covered and braided, wire in twisted pairs, or triplets if required. After the ends of a pair are soldered to the proper terminals on the strip *B*, the pair is led to the nearest of the wooden pins and then along the channel formed between the pins, passing around the one on the opposite side that is nearest to the pair of connectors on the strip *C* to which it is to be joined. This arrangement makes it easy to change the connection of any subscriber's line from any particular switchboard drop to any other, for all that is necessary is to remove the jumper wire and carry it to the new set of terminals to which it is to be attached. In this way, the opening of a cable is rendered unnecessary, no matter what changes are made in the arrangement and distribution of the wires.

39. Connections for Power and Battery Wires. At the left-hand end of the board *A*, which is made considerably longer than the strips *B* and *C*, may be mounted a strip *D*, carrying fuse blocks similar to those used in electric-lighting work. To the terminals of these clips are led the transmitter-battery wires, power-generator wires, and, in fact, all wires that lead to or from the switchboard and are not line wires. These wires leading to the upper side of this strip *D* may be formed into the same cable as that carrying the line wires to the switchboard. On the lower side, however, they are preferably made separate from the line cable, inasmuch as they lead to a separate part of the exchange. The wires to be led from an ordinary switchboard are as follows: Two power-generator wires leading from the terminals marked *P G* on the switchboard to the terminals of the power generator; two transmitter wires leading from the

terminals of the local transmitter circuit on the switchboard to the terminals of the transmitter battery; two night-bell wires leading from the terminals of the night-bell circuit marked *NB* on the switchboard to the terminals of the night-bell battery; and where the switchboard requires a common-return or a grounded circuit, a single wire leading to the common-return wire or to the ground. The ground wire *G* is shown connected to a metal plate extending the whole length of *B*, so that if the carbon lightning arresters are used, as they should be, the lower carbons, all resting on this strip, are grounded.

PANEL DISTRIBUTING BOARDS

40. For larger exchanges, many styles of distributing board have been devised, one of the simplest of which is made by placing the strips containing the connectors for line wires on one portion of a large flat panel, and the terminals to which the switchboard cables are connected on another portion of the same side of this panel. The jumper wires pass through holes bored through the panel opposite the various terminals. In making a connection from any line terminal to any switchboard terminal, the jumper wire is soldered to the line terminal, passed through the nearest hole in the panel, thence across the back of the panel to the hole opposite the proper switchboard terminal, through which it is passed and secured as before. Wooden pins may be arranged on the back of the panel in order to confine the jumper wires to parallel paths, thus preventing a great amount of confusion. Boards of this kind may be readily constructed, and the ingenuity of the designer may be exercised to arrange the various terminals and parts to best meet the exigencies of the case in hand. Such a board may be available for exchanges having several hundred subscribers, although the forms to be described later are much more desirable for large exchanges.

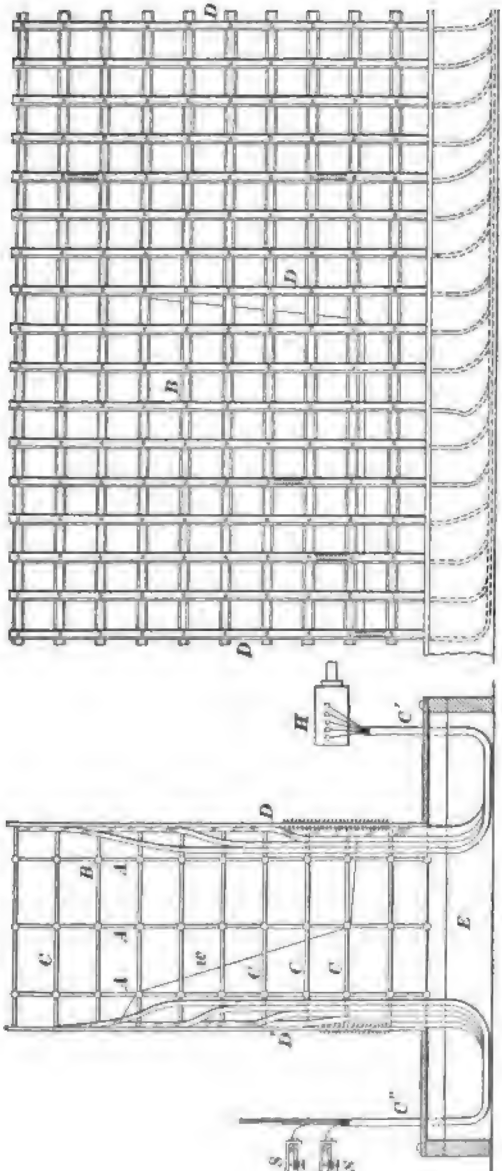


FIG. 17

THE HIBBARD DISTRIBUTING BOARD

41. The **Hibbard distributing board,** designed by Angus S. Hibbard, of the Western Electric Company, has been used to a large extent in the Bell exchanges. It is

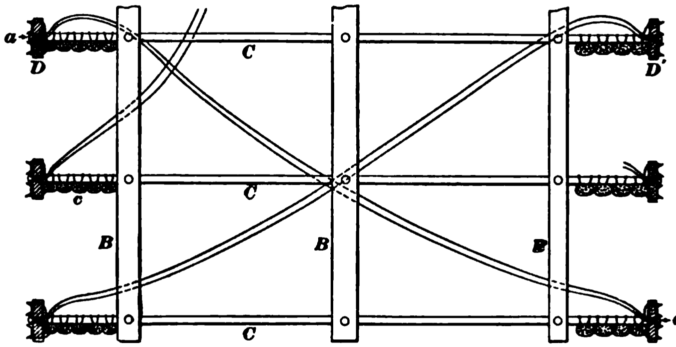


FIG. 18

built in the form of an open framework of iron pipes, or angle irons. Upon the vertical pipes A, A, A, Fig. 17, are mounted the intersecting horizontal pipes B and C, the former extending longitudinally throughout the length of the board and the latter transversely. Upon the ends of the transverse pipes are mounted vertical strips D, D' of insulating material, frequently dry maple wood, which carry the connectors for the various wires of the line and switchboard cables. These cables are brought through a horizontal run box E under the distributing board and are led up to and parallel with the strips D, D', to which they are to be fanned out. The vertical portions of these cables are usually supported by being laced to the projecting ends of the transverse rods C, that is, to the ends between the horizontal rods B and the connector strips D or D'. This is shown in Fig. 18, which is an enlarged plan view of a portion of the board. The terminal strips D, D' are arranged as shown in

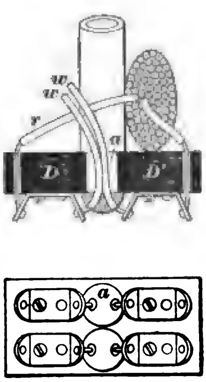


FIG. 19

Fig. 19, the pairs of wires leading from the cable being led to the outside terminals of each connector, while the corresponding jumper wires *w*, *w* are led from the inner terminals of the same pair and through the hole *a*, as shown. This construction applies to both the switchboard and line sides of the distributing frame. The arrangement of iron pipes forms a series of horizontal runs between the vertical and horizontal pipes, and also a series of vertical channels or falls between the intersecting horizontal pipes.

42. Path of Jumper Wires.—In leading from the line side of the distributing board to the switchboard side, a pair of jumper wires *w* (see Fig. 17) passes through the hole *a*, Fig. 18, in the strip *D* and then in a horizontal direction until it reaches the nearest vertical pipe *A*, around which it bends, following one of the horizontal runs until opposite the connector strip on the switchboard side, which carries the pair of terminals with which it is to be connected. The wire is then bent sidewise around another of the vertical pipes *A*, and then downwards or upwards over one of the longitudinal pipes *B*. It follows the vertical run until opposite the particular pair of terminals with which it is to be connected, when it is again bent around one of the transverse pipes *B* and through another hole *a*, Fig. 18, between the proper terminals.

43. Connection of Line and Switchboard Wires. In the end elevation shown in the left-hand portion of Fig. 17, the complete path of the line circuits from the cable heads on which the lines terminate to the switchboard jacks is shown. The cable heads are indicated at *H*, these being devices for facilitating the connection of the various wires in a line cable to other wires in the exchange. The individual wires leading from this cable head are bunched into a cable *C′* that passes into the horizontal run box under the distributing board and are led to a point directly under the terminal strip *D* on which it is to be fanned out. Here the cable is bent upwards and laced to the horizontal rods *C*, as before described, it being fanned out and connected with the outer rows of terminals

on the strip. From the inner rows of terminals, the jumper wires are led through the various channels in the framework to the proper terminals on the switchboard side of the frame. One pair of these jumper wires *w* is shown, and its course may be quite clearly traced. The cable leading from a section of the switchboard is indicated at C''; it is led through the horizontal run box in the same manner as the cable C' and is fanned out on the other side of the distributing board, the connection between the wires in the cable C'' and those in the cable C' being completed, as already described, by the jumper wires *w*.

THE FORD & LENFEST BOARD

44. In very large exchanges, as, for instance, those having multiple switchboards, the **Ford & Lenfest distributing board,** designed for the most part by Messrs. Ford and Lenfest, has been largely used. This board, like the Hibbard, is constructed in the form of an open framework, but the terminals on the line side are usually arranged on horizontal strips, while those on the switchboard side are arranged vertically. The line cables are fanned out on the horizontal strips, which are arranged in tiers, one above the other, and the jumper wires pass through these strips and along horizontal shelves until they are opposite the vertical strip on which the terminals to which they are to be connected are located. The jumper wires are then passed through an iron ring opposite the terminals, and the ends soldered in place, as before. On the vertical side of the distributing board are arranged combined lightning and sneak-current arresters. From the other side of these arresters are led the wires from the switchboard cable, the wires of which are fanned out and permanently soldered to the arrester terminals. The ground plate on which these arresters are mounted is of cast iron, and all the plates on the vertical side are bonded together and connected with the ground in a substantial manner.

45. Cook Frames.—To economize space at the central office and at the same time provide a distributing board,

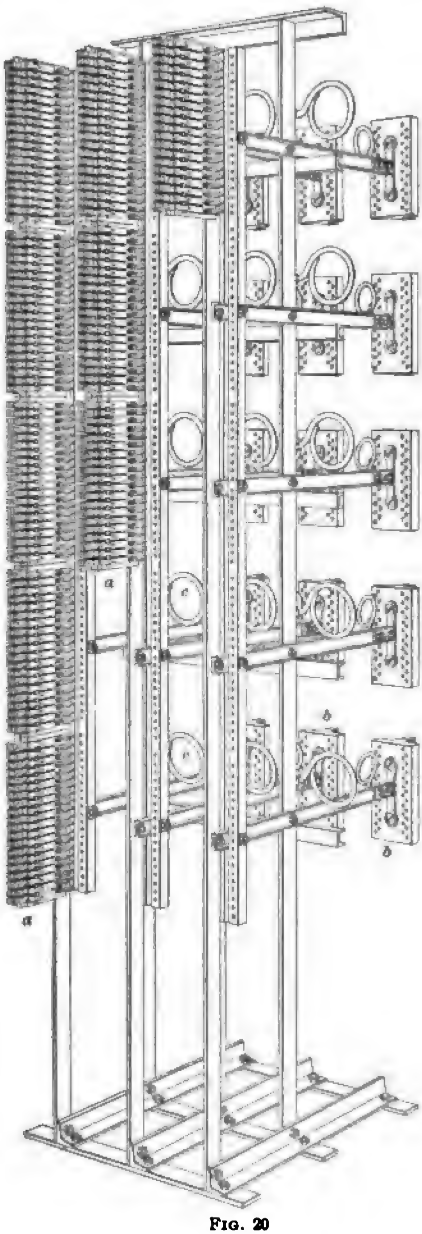


FIG. 20

the **Cook sectional distributing frame,** shown in Fig. 20, was devised. The framework consists of angle irons and channel irons covered with insulating paint and is usually constructed so as to be capable of extension at any time, by merely adding new sections to the frame of that already installed. The protectors are mounted in vertical rows *a*, *a*, while the line terminal blocks *b*, *b*, a front view of one of which is shown in Fig. 21, are mounted on the ends of the cross-bar and form either a horizontal or a vertical row, as desired; the cross-bars form a shelf or support for the jumper wires used in cross-connecting between the protectors and the line terminals. Wherever the jumper wires will bend around an iron part of the frame, enameled rings *c*, *c*, are provided through which the conductors extend, thereby keeping them at a safe distance from

the ironwork of the frame. The switchboard side of the frame is equipped with Cook protectors mounted in banks of twenty or twenty-five pair, as desired, on vertical steel bars $\frac{3}{8} \times 1\frac{1}{2}$ to 4 inches, depending on the size of the frame required. Each vertical contains any number of these twenty or twenty-five pair banks required. The distributing terminals for the line side of the distributing frame are mounted in hard-rubber strips on maple blocks, as shown in Fig. 21, there being twenty or twenty-five pair of terminals on each block; any required number of these blocks, mounted one above the other, may be used to form the vertical side.

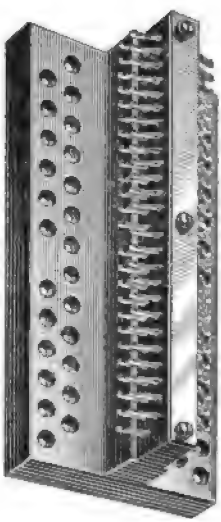


FIG. 21

46. Alarm Circuit.—Instead of wiring the alarm circuit for all of the pairs of protectors to a common alarm bell or indicator, as is frequently done on distributing frames, the following arrangement by Frank B. Cook is coming into use in very large installations. Each side of each vertical row on the protective frame is wired to a lamp signal that is mounted directly on top of that vertical row, and hence always in plain view. When a heat coil operates, it closes the alarm circuit on that side of the vertical row in which it is situated, and thereby causes the corresponding lamp to light, which signifies that one or more heat coils on one side of one vertical row have operated. The signal lamp stays lighted until the protective apparatus is restored to its normal position. In addition to a signal lamp for each side of each vertical strip of protectors, there is a large gong or signaling device wired common to all the signal lamps, to give the general signal when a protector on any part of the board operates. This general signal calls the attendant's attention to the fact that a protective device has operated, in case he is not at a place from which the signal lamp can be

seen. In this arrangement of the protective apparatus and signal lamp, the matter of locating trouble is a very simple one.

47. Arrangement of Jumper Wires.—The object of any distributing board is to render changes in the distribution of the line wires with respect to the switchboard terminals an easy matter at all times and to prevent, as much as possible, any confusion arising in the jumper or bridle wires by which these changes are effected. In large exchanges, much trouble is experienced with an improperly designed distributing board, on account of the jumper wires being tangled and so crowded together as to render their subsequent withdrawal a matter of great difficulty. In such cases, it is not infrequent to find the old jumper wire merely cut loose from the terminals to which it had been connected and left dead in the distributing frame. This brings about subsequent trouble, the idle, or dead, jumper wires adding to the general confusion without being of any service whatever. For this reason, those having the care of distributing boards should make it an absolute rule that whenever a jumper wire is cut loose at its terminals it should be pulled out, even though this entails considerable trouble. The proper arrangement of the jumper wires is a matter of great importance, and the distributing board that best accomplishes this, at the same time maintaining the wires in an open relation, is, other things being equal, the best adapted for its purpose.

INTERMEDIATE DISTRIBUTING BOARDS

48. In the larger exchanges, it is also customary to employ what is termed an **intermediate distributing board,** similar to the main distributing board, except that it is not provided with arresters. Where a series-multiple switchboard is used, the cables go from the vertical side of the main distributing board to the ordinary multiple jacks on the switchboard. From the last jack in each line, cables are led to the vertical side of the intermediate distributing board, cross-connected to the horizontal side, from which cables are

led back to the switchboard, and are there connected to the annunciators and the corresponding answering jacks.

In switchboards where all the jacks, annunciators, or line relays are connected in parallel across the two line wires, the cables run from the main distributing board to the vertical side of the intermediate distributing board, from which the wires branch, before crossing the latter, to the ordinary multiple jacks on the switchboard. Cables from the horizontal side of the intermediate distributing board are connected to the line relays or annunciators and the corresponding answering jacks. Then, by jumpers, any line relay or annunciator and its corresponding answering jack can be connected across the board to any line and its corresponding set of multiple jacks. At the main distributing board, all changes in the arrangement of circuits are made that are brought about by the removal of instruments from subscribers' premises, the replacing of new instruments, or the changing of the subscriber's location.

49. The office of the intermediate distributing board is to permit of the rearrangement of lines leading to any section of the board, or, more properly, to any operator's position. Such rearrangements are often necessary in order to equalize the amount of work performed by the various operators. It is found that some groups of lines will be particularly busy, owing to the fact that their subscribers require many connections per day, while other groups of lines will require comparatively little attention. By means of changes performed at the intermediate distributing board, the number of lines on an exceptionally busy section of the board may be reduced by interchanging some of the annunciators and answering jacks with the sections controlled by operators who are kept less busy, and this is done without changing the subscriber's multiple jacks and his telephone number on them. It is evident that by means of jumpers at the intermediate distributing board, any line and its system of multiple jacks can be connected with any answering jack and its corresponding annunciator.

50. Wires usually enter an exchange in cables; in small exchanges from a cable pole overhead, and in large city exchanges through an underground tunnel, or ducts. A tunnel, which was formerly used quite extensively, is a very good plan indeed, but it costs much more than ducts leading from the nearest manhole to the cellar and in some streets it is impractical on account of the pipes and other obstructions.

In the building, the cables may be run directly to the distributing frame, and there ended, in small systems, in pot heads; for large systems, the cables are terminated inside the cellar wall in pot heads or iron cable heads. Formerly, iron cable heads supported in frames on the wall were extensively used; these carried protective devices and house cables were used to extend the line circuits to the distributing frame. Now pot heads are preferred, as they cost less and seem to be satisfactory; the protective devices being mounted on the switchboard side of the main distributing frame, where about 30 per cent. less line protectors are required than there are lines entering through the pot heads. Formerly, good rubber-covered wires were used in extending the conductors through the pot head, but experience has shown that silk-and-cotton switchboard cable is sufficiently good. Lead-covered, wool-insulated cable is considered better, because wool is less inflammable and does not gather moisture as readily as cotton and silk.

Many claim that pot heads afford a better protection against the entrance of moisture into the cable, that they are cheaper, require less space and less protection of a cheaper and more accessible form (mounted on the switchboard side of the main frame) than iron cable heads; while others claim that iron cable heads with protectors on them protect all the inside wiring, afford better facilities for testing and rearranging circuits when a cable is spliced and that this compensates for their greater cost. Where iron distributing frames, flame-proof insulation, and fireproof construction in general is employed, there is much less likelihood of a fire than formerly when wood was more extensively used. The pot head, which now seems to be the most generally

preferred, will be treated in connection with telephone cables.

51. Probably the best location for the pot heads is on the floor directly under the main distributing frame to which they are connected with twenty-pair switchboard cables. A lead cable, when running vertically, should be allowed to rest with its curved portion on the floor where it changes from a horizontal to a vertical position, and should be firmly secured by clamps to the wall every 10 feet.

The connections through main and intermediate distributing frames have been shown in connection with the Bell and Kellogg central-energy systems.

52. Size of Distributing Frame.—The size of a distributing frame may be calculated as follows: On account of dust, the arresters should not be nearer than 1 foot to the floor and, without a ladder, a man cannot work on a frame over 6 feet high, giving an available space of 5 feet. With arresters set $\frac{1}{2}$ inch between centers, there will be 120 in each vertical row. There will be as many vertical rows of pairs of arresters as 120 will go into the total number of pairs of line wires. To the rows thus calculated must be added 10 to 20 per cent. to allow for trunk lines, order wires, toll lines, etc. The vertical rows may be placed 8 inches between centers, and the horizontal strips on the other side of the frame may be placed 9 inches between centers, giving eight horizontal strips on a frame 9 feet high. The connectors on the horizontal side can be placed $\frac{3}{8}$ inch apart, giving nearly twice the connecting capacity as on the vertical arrester side of the frame. However, only about 30 per cent. more connectors need be supplied on the horizontal-line side than on the vertical-arrester side.

53. Power Wire.—The best quality of rubber-covered and braided wire, sufficiently large to prevent any appreciable drop in voltage, should be used for the power and lighting circuits. The current-carrying capacity and insulation should fulfil all requirements of the National Board of Fire Underwriters. The leads for the transmitters, battery, and ringing

generators should be of rubber-covered and braided wire and not less than No. 18 B. & S. gauge. Each operator's transmitter circuit should be supplied with current through separate battery leads. The main ringing-generator lead should run through all the switchboard sections, taps being taken off at each operator's position. In the ringing-generator taps, there should be placed a resistance to protect the machines when ringing crossed or grounded lines. For this purpose, 110-volt, 16-candlepower incandescent lamps may generally be used.

EXTENSION TELEPHONES

LOCAL-BATTERY TELEPHONE EXTENSION SETS

54. A subscriber often requires two or more instruments connected to the same line with a view of increasing the flexibility of the service. These additional, or auxiliary, instruments, usually termed **extension telephones** are designed

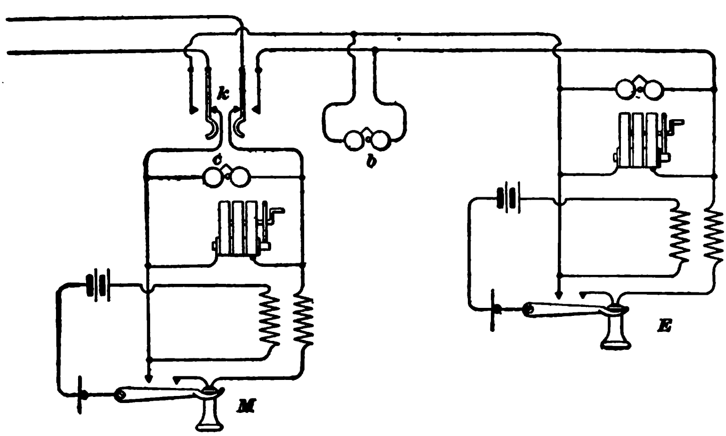


FIG. 22

to perform special functions. They may be connected in several ways, the simplest is that in which the main and auxiliary instruments are permanently bridged or connected in series with the same line, bridging telephones being used

in the former and series telephones in the latter case. The extension instrument may not be provided with a regular bell or generator, in which case all calls are received at and sent from the main instrument. If the party at the auxiliary instrument is required, his attention is called by a buzzer or some such device operated by a battery and a push button located at the main instrument. However, the auxiliary instrument is usually equipped with a generator so that calls

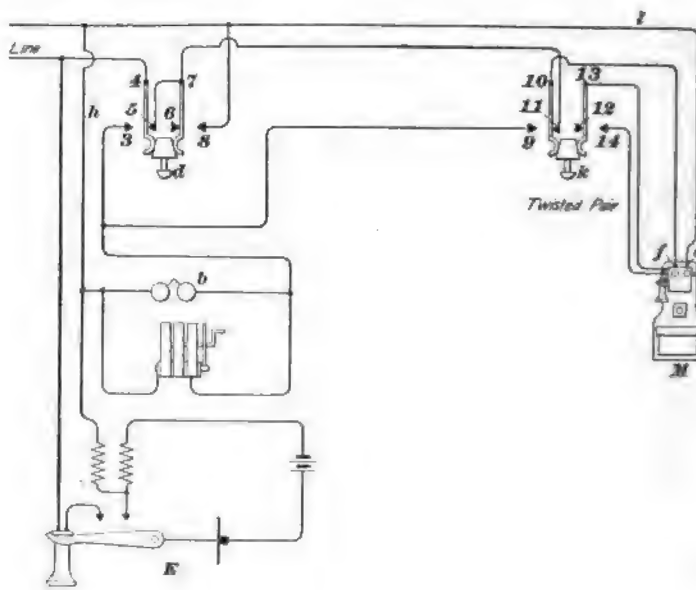


Fig. 23

may be transmitted from this point. The wiring of extension sets will depend very much on the telephone system with which they are to be connected, and also on the manner in which the extension sets are to operate in connection with the main telephone.

55. An arrangement, used by the Bell Company, is to wire the main instrument, as shown in Fig. 22, through a key *k* to the outer points of which is wired the extension instrument *E*. A second bell *b* is bridged across the circuit of the latter, so that the main telephone station may be called up from the

extension instrument. Calls from the telephone exchange are received only at the main instrument. Should the party at the extension instrument be required, the key *k* is thrown so as to cut out the main and cut in the extension instrument. Should the party at the extension instrument desire to transmit a call, he rings the bell *b*, which is of a different sound to that of the instrument bell *c*.

56. It is often desired that the party at the main instrument be prevented from listening to the conversation, and to this end the more elaborate plan shown in Fig. 23 has been devised. Here the calls are received on the main instrument, which is equipped with a ringing key *k*, while the extension instrument *E* is equipped with a listening key *d*. When the listening key *d* is in its normal position, the line circuit is completed through *4–5–7–11–10*–binding post *f* on telephone *M*. A call, therefore, coming in over the line rings the bell of the main instrument *M* over this current, which also serves as the talking circuit. The ringing circuit of the telephone *E* stands open at the contacts *3*, *9* of the keys *d*, *k*, respectively. Should the key *k* be pressed, the circuit is broken between *10* and *11* and made between *10* and *9*, so that when the generator at *M* is turned, current flows from the post *e* through *l–h–b–9–10–f*–bell of telephone *M–e*. When the key *d* only is depressed, the ringing circuit of telephone *E* is closed through *3*, *4* across the line directly toward the central office. Contact is also made between *7* and *8*, which short-circuits the telephone *M*, so that no call can be sent by the instrument *M*, thus insuring uninterrupted conversation at *E*. In order to prevent any one at the telephone *M* from listening to the conversation between *E* and another exchange subscriber by merely depressing the key *k*, a short circuit is thus formed around the receiver through *13*, *14*.

57. In Fig. 24 is shown a modification of this plan to take in two extension instruments *E*, *F*. Here the main instrument *M* is equipped with two ringing keys *b*, *c* wired as shown. The key *b* is for the extension instrument *F*, while

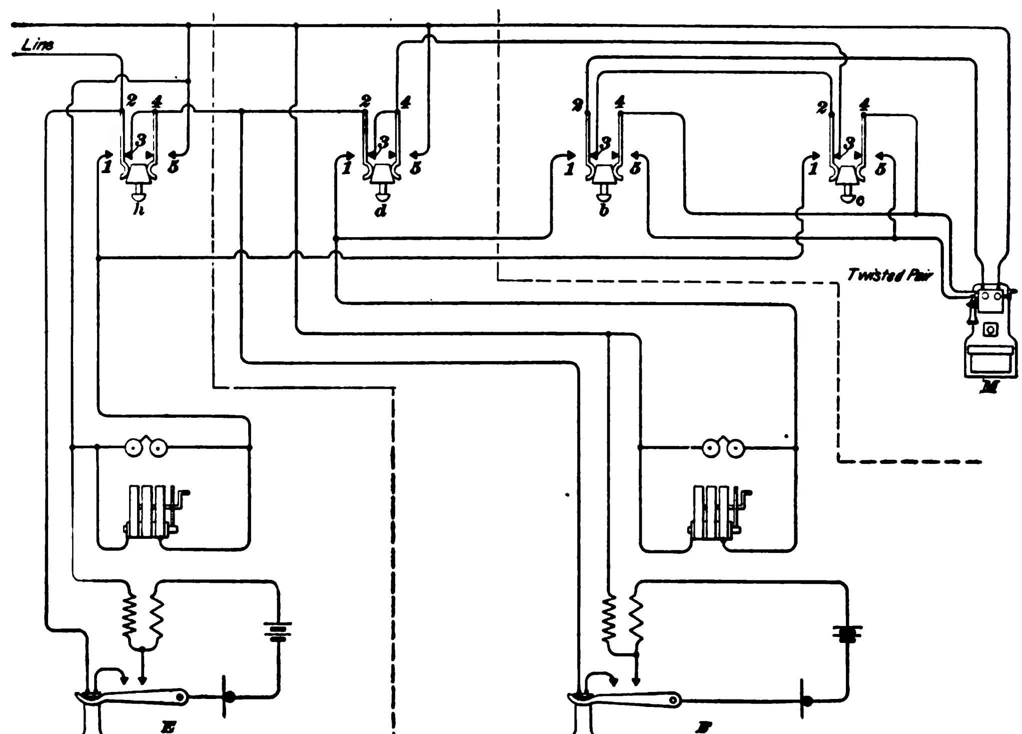


Fig. 24

the key c is connected with E. The keys d, h associated with F, E, respectively, serve to short-circuit M when thrown. Thus the calls are received on M; each extension instrument is called independently from M when wanted, and both E and F are able to short-circuit M and prevent the party there from listening. Also, M cannot interrupt the conversation at either E or F. Many special arrangements are devised from time to time to meet special requests of subscribers; but those described are standard circuits of the Bell Company and are always used by that company unless the subscriber especially requests something else. The above plans were originally devised for use on local-battery systems, but they can be readily adapted to and are used in connection with central-energy systems.

CENTRAL-ENERGY EXTENSION SETS

58. Fig. 25 shows an arrangement whereby the main telephone at station *1*, which is supposed to be connected with a central-energy exchange has control over the extension telephones at the stations *2* and *3*; that is, when the

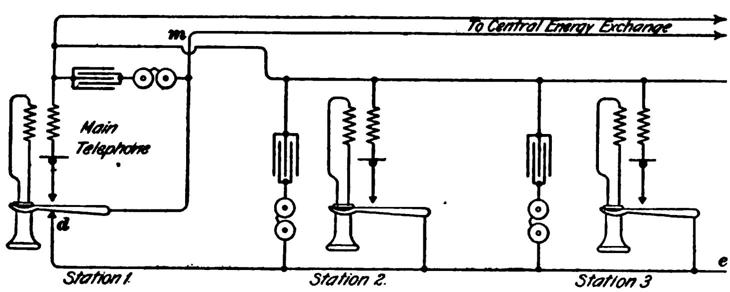


FIG. 25

receiver at station *1* is taken down, the other stations are cut out so that they cannot even listen in. A signal code is, of course, necessary in order that the exchange operator may call up only the one station desired, but the exchange can be called from any station by merely taking down the receiver.

BATTERY-SIGNALING CIRCUIT

59. In Fig. 26 is shown an arrangement using a separate **battery-signaling circuit.** At station *1*, where the main telephone is located, there is one push button for each extension set, one battery *B* used only for ringing ordinary battery bells V_2, V_3 at the extension sets, one wire from station *1* to each extension set, one common return *B–i–e* and two wires *fg* and *de* that run through all the stations. Some one at station *1* must answer all calls from the central exchange; if a party at station *3*, for example, is wanted, push button P_3 is pressed, thereby ringing the bell V_3. The

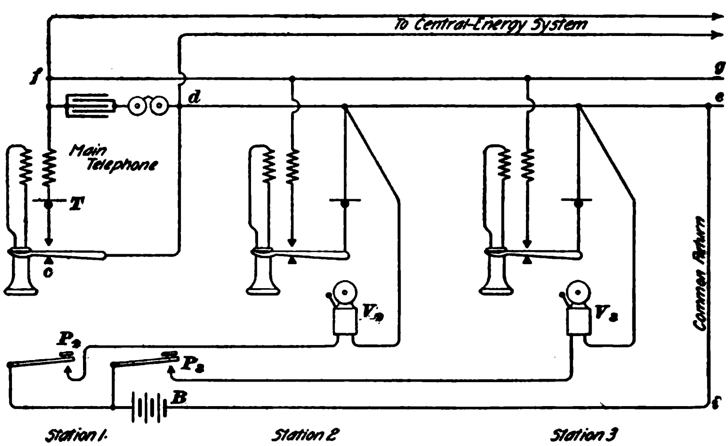


FIG. 26

extension sets can be arranged to be cut out when the telephone at station *1* is in use, by connecting the wire *de* to contact *c*, instead of to the line wire to which it is now connected.

60. **A central-energy extension instrument** may be arranged as shown in Fig. 27, so that when the main instrument is in use the line to the extension instrument is opened at the hook switch. If contacts *c* and *a* are connected permanently together, as is often done, instead of through contacts controlled by the switch, the telephones will still work;

but if the main instrument is in use, a party at the extension instrument can take down the receiver and overhear the conversation, due to the fact that the variation of potential at point *d* will produce a variable static charge in the circuit

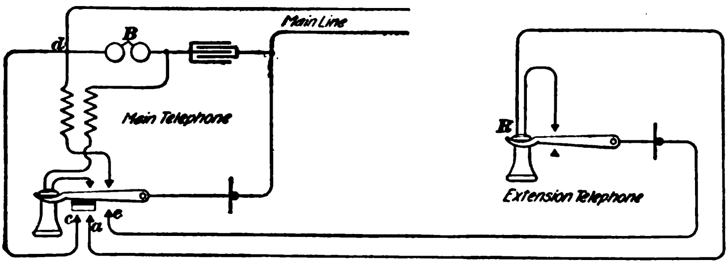


Fig. 27

through the extension instrument, which is open at *e* only, thereby reproducing the same conversation, although it may be very feeble, in the receiver *R*.

61. An ordinary instrument and a key may be used at the main telephone, as shown in Fig. 28, for accomplishing

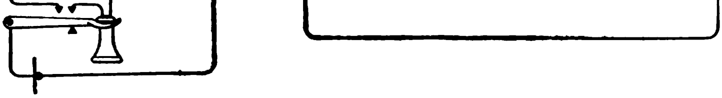


Fig. 28

the same purpose as the arrangement shown in Fig. 27. The extension instruments may be wired as shown here, or in the same manner as the main instruments, with or without a bell.

MAIN AND EXTENSION PRIVATE CIRCUIT.

62. Where it is desirable to use the main and extension instruments of an exchange circuit as a private line without signaling the operator, N. C. Kissel, in The American Telephone Journal, suggests the circuit shown in Fig. 29, which he has found to work in a most satisfactory manner, and at the same time there is nothing to complicate its operation as far as the users are concerned, for the exchange may be called by either party lifting the receiver from the hook. This circuit may be adapted to work on any central-energy system, the vital point being to cut the exchange in and out automatically. *A* is the main telephone and *B* the extension instrument; the bell *V* is connected between the tip conductor *t* and the ground when both receivers rest on their hook switches. *A* must answer all calls from the exchange as the telephone bell *V* is located at this station. If *B* is wanted, the party at *A* presses the button *P*, at the same time keeping his receiver off the hook to hold the line until *B* answers. When either receiver is off the hook, the ground is disconnected and one transmitter and receiver are connected in series across the line wires, thereby keeping the supervisory lamp at the exchange from lighting. If *A* wants to talk to *B* privately, or vice versa, the button *P* or *Q* is pressed, thereby ringing the bell *M* or *F*, respectively, at the other station, and takes down his receiver.

63. Operation.—When *A* takes down his receiver to call central, a circuit is closed from the sleeve side *s* of the line through relay contact *i*–wires *13*, *7*–contact *n*–transmitter-receiver–wire *4* to the tip side *t* of line, thereby operating the line signal at the exchange. If *B* takes down his receiver, a circuit is closed from the sleeve side *s* of line through *i*–wires *13*, *6*–contact *m*–transmitter–receiver–wire *5*, to tip side *t* of line, thereby operating the line signal at the exchange. When the operator rings, current flows through *t*–wire *4*–bell *V*–contacts *o*–wire *17*–contacts *w* to ground *g*. If the party calling should desire *B*, *A* presses his button *P*, thus

closing the circuit from the battery through wires *1*, *2*–push *P*–wire *11*–bell *M*–battery *B*, thereby ringing the bell *M*.

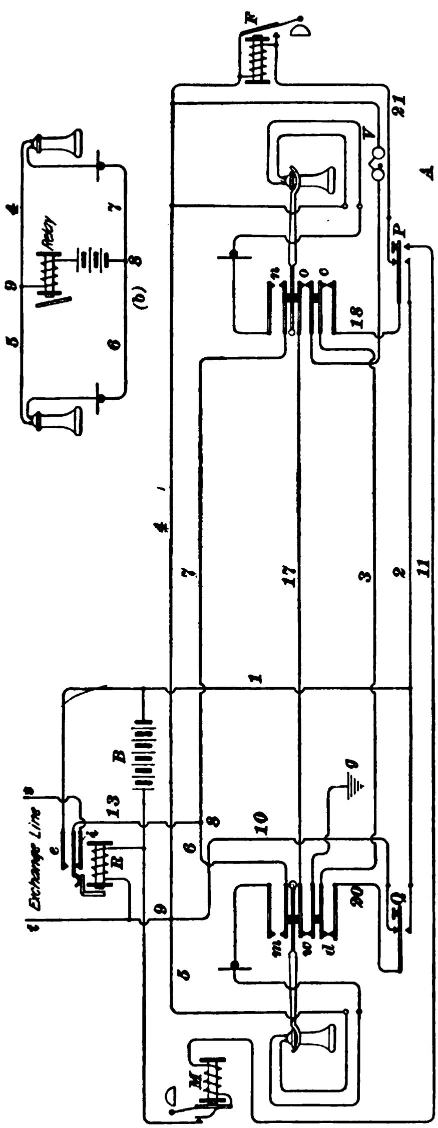


FIG. 29

If *A* desires to speak privately to *B*, he presses his button *P* while his receiver rests on the hook. The current, after flowing from the battery through wires *1*, *2* to key *P*, has two paths back to the battery—one through wire *11* and bell *M*, which it rings, and the other through wire *18*–contacts *c*–wire *3*–contacts *d*–key *Q*–wire *10*–relay *R*–battery *B*, thereby causing the relay *R* to attract its armature. The resistance of the bell *M* is the same as the relay *R*, so the current will divide equally through both. Now, before *A* releases the button *P* he takes down his receiver, breaking one circuit at *c* through the relay, and closing one from battery *B* through relay contact *e*–wires *13*, *7*–contacts *n*–transmitter–receiver–wire

4–relay *R*–battery *B*, thus holding up the relay as long as *A*'s hook is up. The contact at *m* or *n* should be made before that at *d* or *c*, respectively, is opened. When *B* answers, current from the local battery divides at *8*, giving both transmitters current with which to talk. The operator is prevented from coming in as the exchange circuit is open at the lower contact *i* of the relay. The relay, having a high impedance, gives a good-enough transmission circuit, which is shown without details at (*b*).

64. The signaling circuit at *B* is different from the one at *A* and may be traced, when the key *Q* is pressed, from the battery through wire *1*–key *Q*–wire *20*–contacts *d*–wire *3*–contacts *c*–wire *18*–key *P*–wire *21*–bell *F*–wire *4*–relay *R*–battery *B*, the current through this circuit rings the bell *F* and causes the relay *R* to attract its armature. The relay-battery circuit passes, in series, through the lowest pair of contacts on each hook switch; hence, when either receiver is off its hook, this circuit is open. If this was not the case and *A* was conversing with an outside party when *B* signaled, *A* would be cut out by reason of the relay drawing up, but the circuit is open at *A*'s hook and the relay cannot be energized, and vice versa.

The relay should have a large number of turns and be about 100 ohms in resistance. The signal bells *M*, *F* are of the ordinary vibrating type, rewound to the same resistance as the relay, that is, 100 ohms. *M* is an ordinary battery bell whose armature, when attracted, opens the circuit through the bell winding, while *F* is a similar bell, but its armature, when attracted, closes a short circuit around the bell winding. Either bell when supplied with current from a battery will ring, but the bell *F* is arranged not to open its circuit so that it will not cause the relay *R*, with which it is in series when *Q* is pressed, to release its armature. The ringing buttons *P*, *Q* are two ordinary strap keys with top and bottom contacts; an extra contact being placed under *P*.

The number of cells in the battery and the resistance of the relay should both be selected to give about the same

current to each transmitter as it would receive from the exchange battery. When the receivers are hung up, the battery circuit is opened, thereby restoring the exchange connection. A battery of about six ordinary dry cells will operate a 100-ohm relay and give good talking results.

MAIN AND TWO EXTENSION SETS

65. A method of arranging a subscriber's telephone and two extension sets to give privacy on each telephone by the use of two ordinary switchboard keys is shown in Fig. 30,

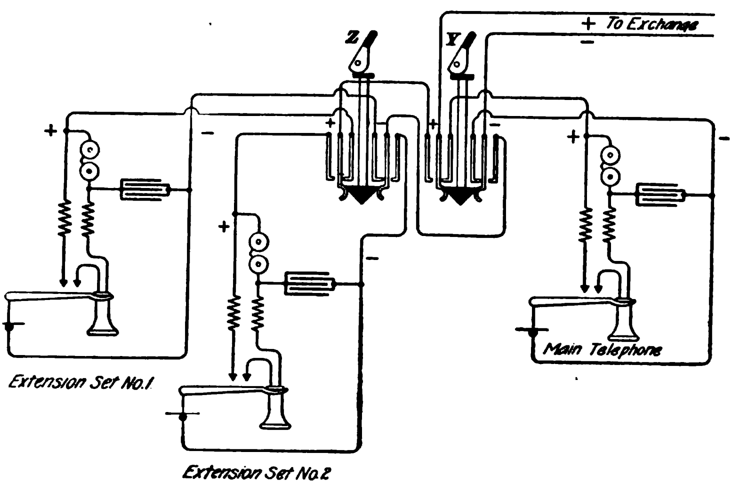


FIG. 30

which was given in The American Telephone Journal by F. R. Pine. The main telephone may be in the business man's private office, and the extension sets located in different parts of his establishment. When he is in his office, the key *Y* is left in its normal position, which allows the main telephone to be connected with the telephone exchange, but cuts off the two extension sets. When he leaves the office to go to some other part of the building, the key *Y* is thrown down, thus disconnecting the main telephone; if the key *Z* is in its normal position, extension set *1* is connected with the

exchange, and the other set is cut out; if key *Z* is also thrown down, extension set *2* is cut in, and extension set *1* is cut out. The proper positions of the keys to connect any one instrument with the exchange can be indicated on a card attached to the stand on which the keys are mounted. When a man leaves his office to visit some other part of his establishment, he generally knows to what part of the place he is going, and can set the keys accordingly.

SIMULTANEOUS TELEPHONY AND TELEGRAPHY

(PART 1)

SIMPLEX AND COMPOSITE SYSTEMS

1. The transmission of telegraph and telephone messages over the same line circuit at the same time is called **simultaneous telegraphy and telephony.** An arrangement of circuits that will allow the transmission of one telephone and one telegraph message at the same time over one pair of line wires is now termed the **simplex system.** When telephone apparatus is substituted for the telegraph apparatus, thus permitting two telephone messages to be transmitted over the same pair of wires at the same time, the arrangement is called **duplex telephony; multiplex telephony** is a term sometimes applied to those arrangements whereby it is possible to transmit, simultaneously, three telephone messages over two pair of line wires.

2. An arrangement of circuits that will allow the trans mission of one telephone and two telegraph messages at the same time over one pair of line wires is termed the **composite system;** this term is also given to a similar arrangement of apparatus that will allow the transmission of one telephone and one telegraph message at the same time over a single line wire. In the latter arrangement, the ground is used as a common return for both the telephone and telegraph currents.

SIMPLEX TELEPHONY AND TELEGRAPHY

IMPEDANCE-COIL METHOD

3. M. Cailho, a Frenchman, was about the first to devise a simplex system using impedance coils. The essential feature of his arrangement, which is shown in Fig. 1, consists of an *impeaance*, *retardation*, or *choke coil*, as it is variously termed, composed of two identical windings *D*, *E* of insulated copper wire, each having exactly the same resistance and the same

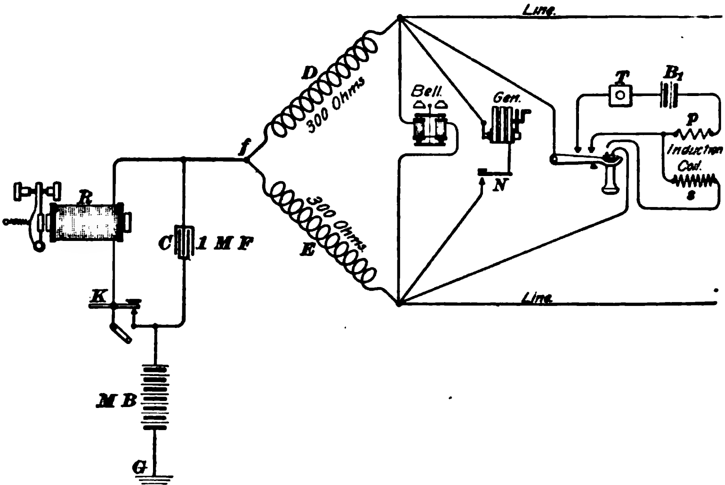


FIG. 1

number of turns wound on the same soft-iron core. *R* is a telegraph relay of about 500 ohms resistance, *K* a telegraph key, which is provided with a switch to short-circuit the key when it is not being used for sending a telegraph message, and *M B* is the so-called main-line battery used for operating the telegraph relays. The telegraph relay *R* controls a local circuit containing a telegraph sounder and a so-called local battery. This circuit will be shown in other figures.

In Fig. 1, *N* represents a manual or automatic device that normally keeps the generator circuit open. When the generator handle is turned, the circuit must be closed at *N*, either

automatically or by hand. T and B_1 represent the telephone transmitter and battery, respectively, and p and s, the primary and secondary windings, respectively, of a telephone induction coil.

4. The telegraph currents divide at the point f into two equal parts, since the two paths have equal resistance, and pass through the two windings in opposite directions around the iron core, so that the two coils tend to magnetize the iron core equally, but in opposite directions; consequently, the self-induction will be practically zero and the impedance to the telegraph current will be no greater than the resistance. For the telephone currents, however, the case is different. They not only have to pass through the two halves D and E in the same direction around the iron core, but their frequency is very much greater; consequently, the impedance offered by the coil to the telephone current will be very large, thus practically forcing all the current coming from the distant station through the telephone where it belongs. Thus the coils prevent the telephone currents from passing through them, but as they add only one-half the resistance of one coil to the telegraph circuit (since there are two coils in parallel), they do not interfere appreciably with the telegraph signals.

If care is taken that the two halves D and E of the coil have exactly the same resistance and number of turns, and that the two line wires are reasonably equal in resistance, clicks in the telephone will not seriously interfere with talking, although they may sometimes be heard. However, if the clicking is found to be objectionable it may be almost, if not entirely, obliterated by connecting a condenser C of 1 or 2 microfarads capacity around the telegraph relay and key at each station. The fundamental principle on which this method depends is extensively used.

5. Dimensions of Choke Coils.—Two or three styles of choke coils are used. The one used by the Pacific States Telephone and Telegraph Company has an iron core $\frac{5}{16}$ inch in diameter, a length between heads of $3\frac{1}{16}$ inches, and is wound to a depth of about $\frac{1}{8}$ inch with No. 36 B. & S. copper

wire, giving a resistance of 600 ohms. If wound with No. 31 B. & S. wire, this same choke coil will have a resistance of about 50 ohms. The whole is iron clad, that is, closed by an iron cylindrical shell $\frac{1}{16}$ inch thick and by two iron end plates. The iron parts are firmly fastened together by a screw at each end. The induction coil is the one generally used by the Bell Companies in their bridging telephones having 1,000-ohm bells and White solid-back transmitters. The secondary winding of the induction coil has a resistance of 14 ohms, and the primary winding a resistance of $\frac{1}{2}$ ohm.

M. Cailho successfully used coils of lower resistance at *D* and *E*, but the induction was made high. For long line circuits, *D*, *E* should each be choke coils of at least 600 ohms resistance. Morse relay magnets, having a resistance of 500 or 600 ohms, or 1,000-ohm telephone-bell magnets, as will be shown in Pfund's system, may be used in place of special impedance coils. Where Morse relay or bell magnets are used, the point *f* will be the junction of the two coils. The talking qualities of the telephone are not interfered with and ordinary bridging telephones may be used.

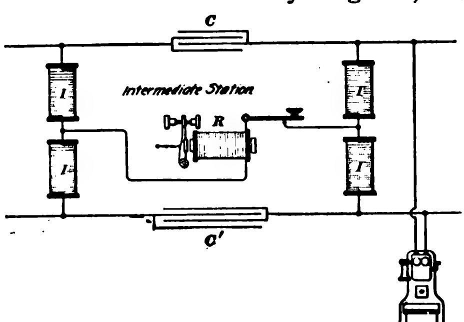


Fig. 2

6. Intermediate Telegraph Station.—An intermediate telegraph station may be obtained by the arrangement shown in Fig. 2, in which *I*, *I*, *I*, *I* are 600-ohm retardation coils. In each line is inserted a condenser *C*, *C'*, while an ordinary bridging telephone is connected across the two line wires. The capacity of the condensers need not exceed 2 microfarads.

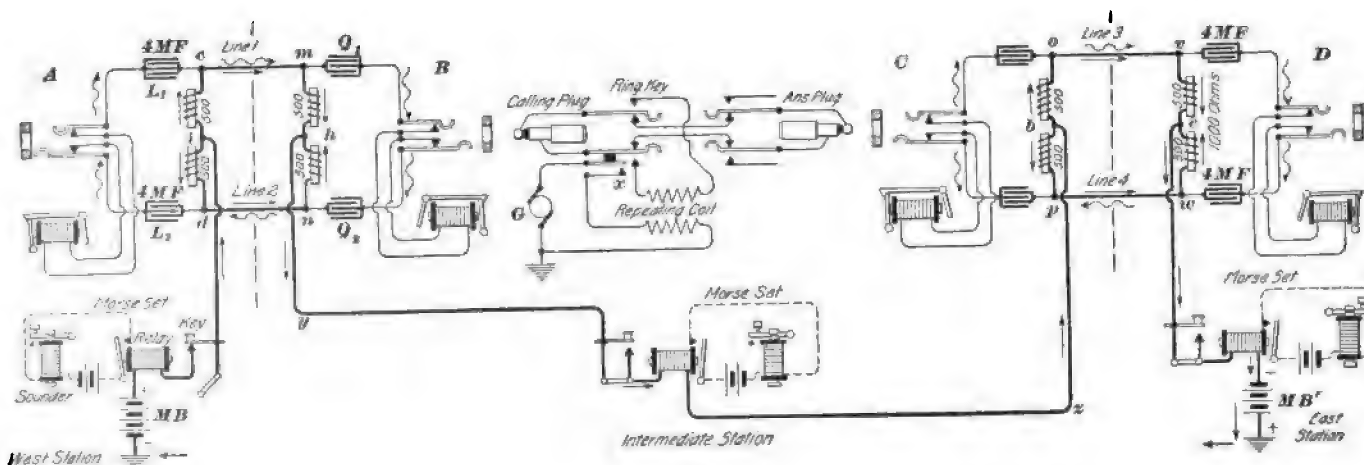

A
4 M F
L_1
4 M F
L_2
c
d
Line 1
Line 2
m
n
Q_1
Q_2
500
500
h
B
Calling Plug
Ring Key
Ans Plug
x
Repeating Coil
G
C
D
o
p
b
Line 3
Line 4
v
w
1000 Ohms
Morse Set
Sounder
Relay
Key
M B
West Station
y
z
Intermediate Station
M B'
East Station

FIG. 3

BELL SIMPLEX SYSTEM

7. The Bell long-distance companies have used the system shown in Fig. 3 with excellent success. It will be seen to closely resemble M. Cailho's method. The telegraph circuit is connected to the center i of a retardation coil $c\,d$, which has a total resistance of 1,000 ohms and is bridged across the line. From $c\,d$, wires run to two condensers L_1, L_2 of 4 microfarads capacity each, and from there to a jack and drop located at the toll switchboard. From c, d, the wires also run to a test board, the main distributing frame, and to the toll line wires *1*, *2*. Similar retardation coils $m\,n, o\,p, v\,w$ are connected across the line wires at each exchange. In fact, the entire arrangement at each exchange A, B, C, D is similar.

8. The principle of operation is as follows: Current from the main-line Morse battery $M\,B$, Fig. 3, passes through the two halves of the 1,000-ohm coil $c\,d$ in multiple, thus flowing through a resistance of one-half of 500 = 250 ohms. The impedance of this coil tends to take off the sharp points of the current wave, so that by the time the current reaches the points c and d, it varies along a smooth sine curve. The two 4-microfarad condensers L_1, L_2 being impervious to currents of the relatively low frequency of the telegraph current, none of it finds its way to the telephone circuit, but all passes out over the line. At the receiving office B, the same condition prevails; the current, passing through the retardation coil $m\,n$, reaches the Morse set in preference to passing through the condensers Q_1, Q_2 and disturbing the telephone circuit.

The telephone current readily passes through the condensers, but not through the retardation coils, which are bridged across the line wires, because the impedance of one retardation coil $c\,d$ for the high-frequency telephone current is equivalent to a total resistance of about 30,000 ohms; hence, it follows that little or none of the telephone current will be shunted through any impedance coil. At the receiving office

B, the conditions are the same, since the telephone current passes through the condensers Q_1, Q_2 in preference to flowing through the retardation coil $m\,n$. The straight arrows indicate the path taken by the telegraph current, while the wavy arrows indicate the path of the telephone current.

The impedance coil used consists of four windings, or separate coils, on the same iron core, the four windings being connected in series across the line wires, so that any current passing from one line wire through the coil to the other line wire must pass through the four windings in the proper direction around the iron core, so as to assist each other in magnetizing the iron core in the same direction, thus giving the whole coil a maximum inductance for such currents.

9. Intermediate Stations.—With the **Bell simplex** system a number of Morse sets can be worked together on the same line. In Fig. 3, three Morse instruments are shown connected in series in a circuit which is subdivided so as to allow the use of two independent telephone sets at the same time. Thus a through telegraph circuit may be obtained from the exchange A through the two exchanges B, C to a fourth exchange D. B and C may be the same exchange or they may be exchanges in different places with the intermediate telegraph station located anywhere along the single line wire y, z that connects them. If no intermediate telegraph station is required and exchanges B, C are some distance apart, the points h, b may simply be connected together by a line wire.

If an intermediate telegraph station is required on a through pair of telephone wires, then connect the Morse set at the intermediate station as shown and connect m through a condenser to o and n through another condenser to p, the jacks, drops, and other condensers at stations B, C being omitted. The connections would then be the same as shown in Fig. 2.

10. All the cells required to operate telegraph relays may be located at any station, or they may be divided equally

or otherwise among all the telegraph stations, or about half the cells may be located at each end station. The last is usually the most convenient as well as the most satisfactory. All cells or batteries used in the same telegraph line circuit should be connected in series. For this reason, it will be noticed that the negative terminal of MB and the positive terminal of MB' are grounded.

11. Western Electric Impedance Coil.—The 1,000-ohm impedance, or retardation, coil, as constructed by the Western Electric Company, and used by the Bell Company in its simplex systems, is shown in Fig. 4 (*a*). On each

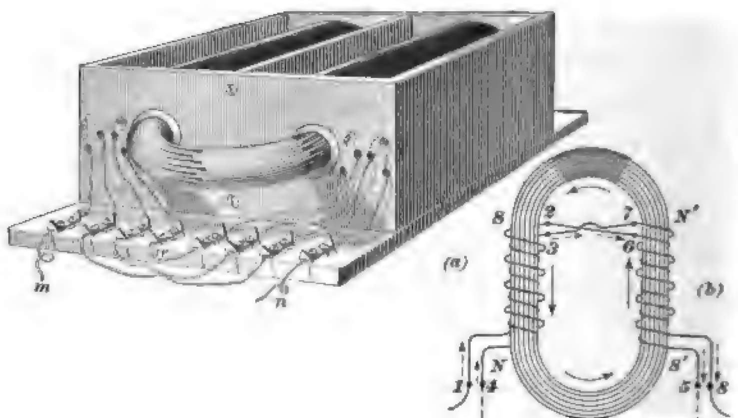


FIG. 4

spool there are two windings, one over the other; the inside winding on one spool is connected to the outside winding on the other spool, as indicated in Fig. 4 (*b*), so that the maximum amount of magnetism is produced in the iron core by the current flowing through the coils in series. The two coils on the left spool must each tend to produce a north pole at N and a south pole at S, and the two coils on the right spool, a north pole at N' and a south pole at S', as indicated in the figure. The telegraph circuit is connected to the center of the coil at e. The core is made of a bundle of fine iron wires, the ends of the bundle being interlaced and held in place by the wrapping of iron wire. The

terminals of the windings are brought out to clips, numbered in the manner shown in Fig. 4 (*a*), for convenience in connecting. The dotted coils in Fig. 4 (*a*) merely indicate the windings on the spools. The coil is mounted on a wooden base and protected with a case made of ½-inch wood.

12. Simplex Coil.—An impedance coil used by independent companies and suitable for use on a duplex telephone or simplex circuit is shown in Fig. 5. It has four windings *a*, *b*, *c*, *d*, each containing 2,400 turns of No. 29 B. & S. silk-covered copper wire. One half is formed by connecting together windings *a*, *d*; the other half by connecting together windings *c*, *d*. Each half will have a resistance of 120 ohms. The iron wires forming the core

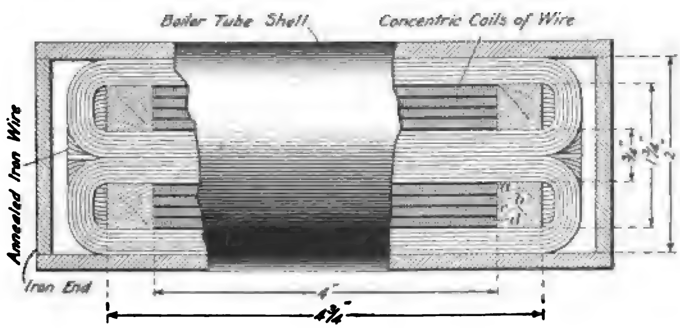


Fig. 5

are 13⅜ inches long, and are bent back so as to overlap around the outside of the coils. To prevent cross-talk between neighboring impedance coils each is enclosed in a shell of iron, as shown. On account of its great impedance and in spite of its low resistance, this coil may be used across a line having 1,600-ohm bells. The coil may be wound with 4,800 turns of two No. 29 wires side by side; this will give a better balanced coil, but it is rather difficult to wind and is more liable to break down, as the potential between two parallel wires is greater in this arrangement.

13. It is quite permissible to ring on an impedance-coil simplex circuit with an ordinary generator that is not grounded, as the inductance of the impedance coil is so great

that very little of the ringing current can pass through it. If a grounded generator is used, however, it will affect the Morse circuit to some extent, especially if the relays are adjusted to work with a small change in the strength of the current or, as telegraph operators say, to work with a small margin.

In case it is necessary to use a grounded generator to ring on a simplex circuit, the current from the generator G, Fig. 3, may be passed through one winding of a suitable repeating coil, the other winding of which, being free from a ground, may be connected to the regular ringing key, which should, however, be provided with an extra pair of contacts x, which closes the generator circuit when the key is closed. All interference with the telegraph relays will be avoided by this arrangement.

Since the Morse current affects both line wires and both condensers L_1, L_2 at the same time and equally, there is no effect whatever from it in the telephone receiver; the telephone is even more quiet than usual because of the bridging of the impedance coils across the circuit.

14. Advantages and Disadvantages of Impedance-Coil Simplex.—The impedance-coil simplex system is much cheaper to install than the composite. It also possesses the advantage of enabling the telephone operator to signal in the usual manner with an ungrounded generator without affecting the telegraph instruments. Furthermore, a number of telegraph stations may be connected in the same line circuit.

The principal disadvantages of the impedance-coil simplex system are as follows: It gives but one telegraph circuit over a pair of wires, whereas the composite gives two telegraph circuits over the same pair of wires; interference with the telegraph service results when signaling with generators that are accidentally or permanently grounded. This trouble may be remedied by the use of an ungrounded generator, but the same circuit is often connected to other long-distance lines extending to many offices, any one of which, by ringing with a grounded generator, interferes with the telegraph service.

Another objection is that unless condensers are used between the impedance coil and the terminal of the line on the toll board, the Morse circuit is liable to become grounded and the Morse service interfered with by the connection of this circuit by the toll operator to another long-distance line that is accidentally grounded. The last two objections may be eliminated by terminating the simplex lines in smaller jacks on the toll board, and using connecting cords that contain repeating coils and terminate in one large and one small plug. This slightly interferes with the rapid handling of the telephone traffic and the repeating coil cuts down the talking efficiency somewhat.

15. For the best service with the simplex circuit using impedance coils, the total resistance of the Morse sets should be high, that is, each telegraph relay should be of high resistance, at least 150 ohms and preferably about 500 ohms. It is not necessary that the resistance of the impedance coils should be so very high, but only their inductance. As already shown, a ringer may be used as an impedance coil, its terminals being bridged across the telephone line, and a telegraph circuit attached to the junction of the wires between the two spools. If the coils are at all equal, this arrangement will be quite successful. If a number of circuits are so equipped, the ringers must not be placed too close together with cores parallel, or cross-talk between the circuits will result. Cross-talk may be prevented by placing the adjacent ringers with their coils at right angles to each other. A high-impedance tubular drop with an accessible middle terminal may also be used for the impedance coil and no cross-talk will result. If high-resistance ringers and drops are used, the telegraph relays should have a high resistance, 500 to 1,000 ohms.

16. Signaling on a Simplex Circuit.—It is said that signaling over a simplex circuit may be accomplished by the arrangement shown in Fig. 6, in which xy is the impedance coil used in simplex systems, R an ordinary receiver connected to the jack J in the same manner as an ordinary drop. T is a transmitter in front of which is permanently fixed a

receiver *H* and *V* is an ordinary battery bell with the vibrating contact disconnected, so the bell will give a single tap on the transmitter case when the circuit through its coils is closed at *n*. The receiver *H*, transmitter *T*, bell *V*, and induction coil *s*, *p* may be permanently mounted in an empty bell box having binding posts *a*, *b*, *c*, *d*, *e*, *f*. The battery *B* consists of four or five primary cells. *P* represents an ordinary calling plug and *K*, the ringing key provided with an extra pair of contacts *n*. When *K* is closed, the contacts *n* will also be closed, thereby allowing current to flow through *B*–*T*–*V*–*p*–*d*–*n*–*c*–*b*, which will cause *V* to tap the transmitter

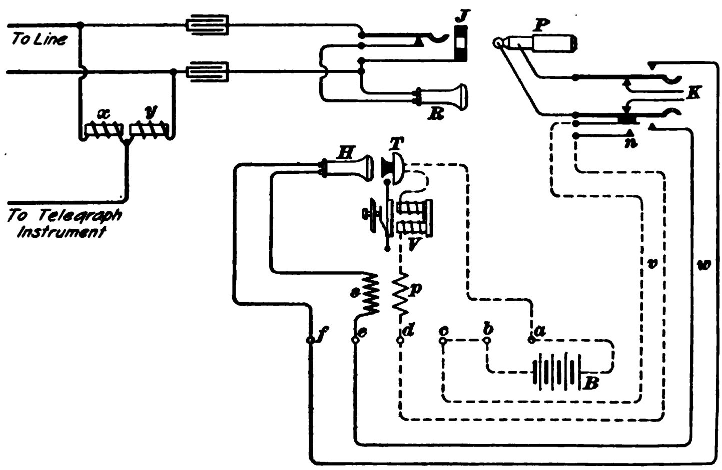


FIG. 6

once, thus starting it to vibrate. If the receiver circuit is also closed, the latter will also vibrate and the transmitter and receiver will continue to vibrate in sympathy with each other until the receiver circuit is opened at the distant station, or the battery circuit opened at *n*. If *P* is inserted in the jack of a line and *K* is closed, the distant receiver, which is connected to the line in the same manner as *R*, will give forth a sufficiently loud howling sound to attract the operator's attention. This arrangement has the disadvantage of giving the operator only an audible signal and could be used only where there is but one or two such simplex currents.

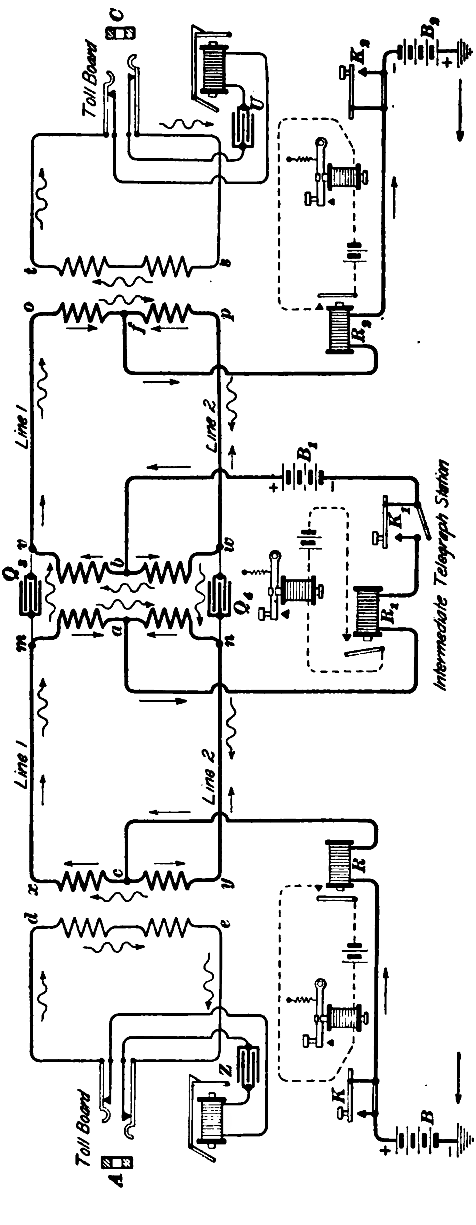

Toll Board
C
Line 1
Line 2
Intermediate Telegraph Station
Toll Board
A

FIG. 7

The distance between H and T and the number of cells used at B may be adjusted, when the apparatus is originally set up, until the desired sound is produced. If desired, this set may be connected to a plug used solely for signaling on such circuits; in which case the wires w will run directly to the signaling plug, the wires v will run to a simple push button, and the signaling plug, after signaling on a line, will be withdrawn from the jack and a regular calling plug inserted in its place. This arrangement of these circuits may also be used as a howler to call a subscriber who has left his receiver off the hook.

REPEATING-COIL METHOD

17. A simplex system may also be secured by the use of repeating coils, as shown in Fig. 7, in which de, xy represents a repeating coil at station A; mn, vw, a repeating coil at any intermediate station; and op, ts, a repeating coil at station C. The repeating coil at the intermediate station is bridged by condensers Q_3, Q_4. The repeating coils and condensers are inserted permanently in the circuit wherever a telegraph tap is desired. Coils may now be purchased with a connection made to the center of one or both windings for this purpose.

18. When all the telegraph keys K, K_1, K_2 are closed, all the telegraph relays R, R_1, R_2 will be closed by current that flows from the battery B through key K and relay R to the middle of one winding of one repeating coil; there it will divide equally, one half passing through line *1* and the other half through line *2*, to the point a, where the two halves unite and pass through the relay R_1, the key K_1, and battery B_1 to the point b, where the current again divides equally, half flowing through line *1* and half through line *2* to the middle f of another repeating coil, where they again unite and flow through the relay R_2–key K_2–battery B_2–ground to station A. If the two sides of the line are equal in resistance, inductance, and capacity, the telegraph current

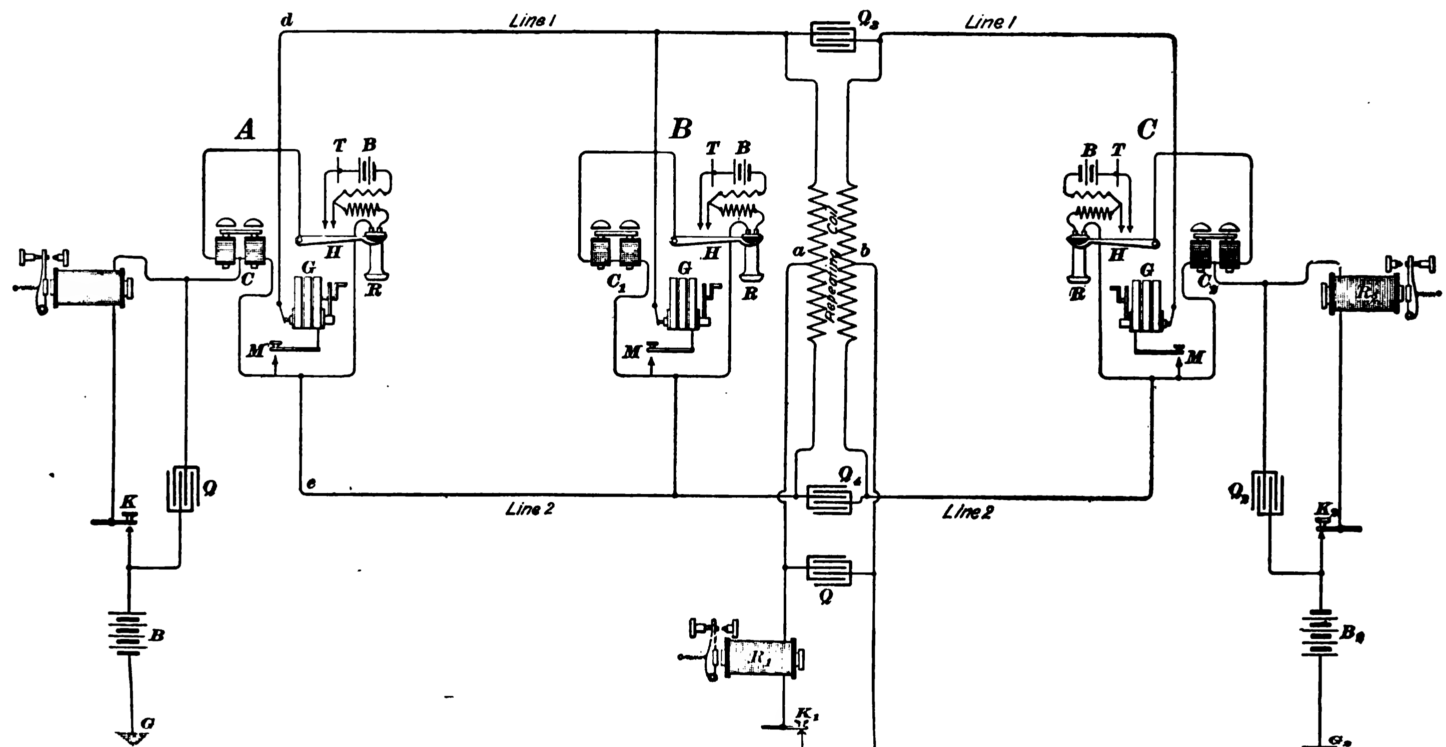
will flow equally through lines *1* and *2* and produce no difference of potential between such points as x, y, no matter how much the telegraph current may fluctuate. Consequently, no disturbance will be produced in the telephones connected across such points as d, e; thus the telephone instruments will not be disturbed by the telegraph currents. When any one telegraph key is opened, all telegraph relays will open.

The fluctuating voice or ringing current will flow through d, e and produce, by induction, a difference of potential between the points y, x, as a result of which an alternating current will flow from x through m–a–n–y. By electromagnetic induction in the repeating coil $m\,n$, $v\,w$, and electrostatic induction in the condensers Q_3, Q_4, an alternating current will be produced in the circuit v–o–f–p–w. An alternating current will then be induced in s, t, which will affect the telephone devices located at *C*.

As long as the line is well balanced, there will be little or no tendency for the telephone currents to flow through the telegraph instruments and ground. The use of condensers *Z*, *U* in series with the drops makes their operation more reliable.

Where no intermediate telegraph station is desired, it is better to omit the intermediate repeating coil and the condensers Q_3, Q_4, line *1* being continuous from x to o and line *2* from y to p. In Fig. 7, one-third of the total number of cells required to operate the telegraph relays are connected in series in the line circuit at each telegraph station. However, half the total number of cells may be located at each end station, or all of them at any one station.

19. Advantages and Disadvantages.—The **repeating-coil method** has the advantage that regular cord circuits and ringing machines may be used in connecting together two such telephone circuits without affecting the telegraph apparatus adversely. It has the disadvantage that the introduction of two repeating coils in a circuit causes a distinct loss in the transmission of both voice and ringing currents; the greater the number of circuits so connected



Line 1
Line 1
Line 2
Line 2
d
e
A
B
C
T
B
H
G
R
M
C
C1
C2
Q
Q2
Q3
Q4
K
K1
K2
B
B2
G
G2
R1
R2
a
b
Repeating Coil

FIG. 8

together by repeating coils, the greater is this loss in efficiency. For this reason the telephone service over the repeating-coil simplex system is very inferior, if the telephone circuit passes through a number of stations.

The repeating coils must be especially designed to transmit both voice and ringing currents. Such coils are not good for transmitting voice currents over long toll circuits. This system is open to the objection that the telegraph service is very apt to interfere with the telephone service in two ways: First, if there is a slight ground on one side of the line, it causes a greater flow of the telegraph current through the corresponding half of the repeating coil, which will allow the clicks to be heard in the telephone; second, if one side of the line is of higher resistance than the other, which is almost always the case to some extent, it causes an unequal division of the current, which produces a disturbance. The same disturbance is noticeable if the windings of the repeating coils are not perfectly balanced. This arrangement is recommended only for short lines.

PFUND'S SYSTEM

20. Pfund's method for telephoning and telegraphing over one pair of line wires at the same time is shown in Fig. 8. It is a combination of the impedance- and repeating-coil methods. The two line wires form the two sides of the telephone circuit. For telegraphing, however, the two line wires are used as one side and the earth as a return. Three stations *A*, *B*, *C* are shown, *A* and *C* being terminal stations and *B* an intermediate station anywhere between the other two. There are in addition to the usual apparatus, a number of condensers, and at the intermediate station a repeating coil, having the same number of turns in the two windings and a closed magnetic circuit of iron. Bells wound to a resistance of at least 1,000 ohms should be used. The repeating coils and the condensers Q_3 and Q_4 are used only where it is necessary to insert an intermediate telegraph station.

21. The telephone current will be confined to the two line wires and will not flow through the telegraph instruments and ground, because the bells and relays offer a much greater impedance to the talking current on account of its fluctuating character than do the line wires, the condensers Q_1, Q_2, or the repeating coil.

The condensers that are connected across the keys and relays not only reduce sparking at the keys, but also prevent a too sudden rise or fall in the strength of the telegraph current in the line wire. The inductance of each half of the bells C, C_2 also tends to reduce the rapid rise or fall in the strength of the telegraph current. In this system, it is possible to carry on a conversation over two line wires between any of the stations connected by them, and at the same time to telegraph over the same circuit, using the two line wires as one conductor and the earth as the return. No special apparatus is required; the repeating coil and the high impedance bells are the same as regularly used in telephone systems.

22. In both the impedance- and repeating-coil methods, the telegraph current does not interfere with the telephone service because the telephone apparatus is connected to points in the circuit between which the telegraph current produces no difference of potential. Broadly speaking, the non-interference of telephone and telegraph currents in simplex systems is not dependent on a considerable difference in the frequencies of the telegraph and telephone currents, but only on the fact that the telegraph current flows over both sides of the line, which are in parallel, in the same direction, using the ground as a return circuit, whereas the telephone current is confined to the metallic circuit and flows through the two sides in series, the ground not being used as any part of the telephone circuit.

23. Same Battery for Both Relay and Sounder. Where it is desirable to operate the local sounder with the same main battery that operates the relay, the arrangement shown in Fig. 9 may be used. M represents the repeating

coil used in some simplex systems; *B*, the telephone-exchange storage battery; *D*, the exchange distributing frame; *L*, the loop line to the telegraph instruments, which may be located anywhere in the same city; *K*, the telegraph key; and *r*, a non-inductive resistance, which should have such a value that the sounder *S* will receive no more current than it requires. If the relay *R* and sounder *S* each have a resistance of 150 ohms, and *B* develops 20 volts, *r* may be 500 ohms. For every increase of 20 volts in the battery, add about 500 ohms to *r*.

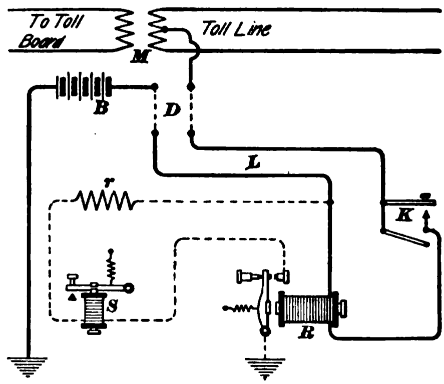


FIG. 9

COMPOSITE TELEPHONY AND TELEGRAPHY

24. One of the difficulties to be overcome in attempting to telegraph and telephone simultaneously over the same line wires by the composite system is the prevention of telegraphic signals being heard in the telephone receiver. Unless this is done, much annoyance will be caused those using the telephone; besides, the secrecy of the telegraph will be destroyed. The wasting of the telephone currents in the telegraph instrument must also be avoided.

In a simple, short telegraph circuit, the current will rise to its maximum value almost instantly when the key is closed and fall to zero almost instantly when the key is opened. A curve representing the current in such a circuit is about as shown in Fig. 10. The time required for the current to reach its maximum value, even on an overhead line of

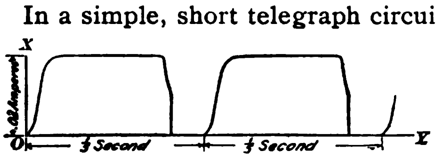


FIG. 10

350 miles in length, is ordinarily less than one-fortieth the time required to make a dot. In telegraphing at the rate of twenty-five words a minute, which is equivalent to about five Morse signals a second, there would be, if means were not taken to avoid it, ten intense clicks every second in a telephone receiver connected between the line wire and the ground, one of these being made every time the telegraph key was closed and another every time it was opened, due to the very rapid rise and fall of the relatively large telegraph current, which may be about one hundred times larger than the telephone current. If the telegraph current is made to rise and fall gradually enough, the telephone receiver will not make any click. The accomplishment of this result has made possible this method of simultaneously telephoning and telegraphing over the same wire.

25. It is a well-known fact that the sudden rise and fall of a current in a circuit can be delayed, that is, made more

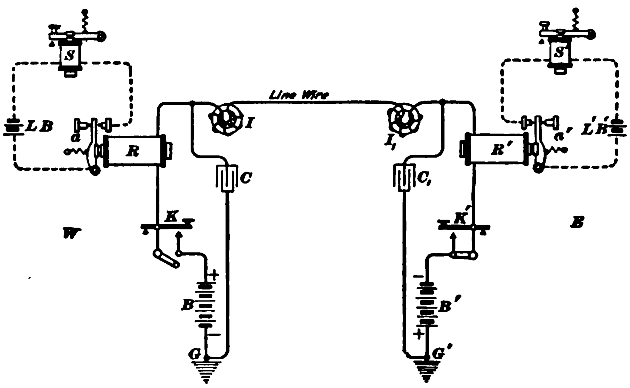


Fig. 11

gradual, by increasing the inductance in the circuit. Furthermore, if in addition to the inductance or impedance coil a condenser is connected from the line to the ground, the current in the line will rise and fall still more slowly. Hence, by using enough impedance coils and condensers, the current in the line may be made to rise and fall as slowly as desired. A simple telegraph circuit, with two impedance

coils I, I_1 and two condensers C, C_1 connected in the circuit, is shown in Fig. 11.

The *impedance* coils I, I_1 consist of a large number of turns of insulated copper wire over a soft-iron wire core, the ends of the iron wire being brought together and overlapped, as indicated in Fig. 12, so as to form a closed iron circuit for the magnetic lines of force. With a given number of turns of insulated copper wire and a given cross-section of iron, such a closed magnetic circuit will give a maximum inductance, causing a maximum opposition to a rapid rise or fall of the current. In making such a coil, it is of much more importance to have a large number of turns of copper wire and a good magnetic circuit of iron than to have a large resistance. In fact, the smaller the simple resistance can be kept the better, provided that there are a sufficient number of turns. Low resistance and a large number of turns means a large coil, because large-sized copper wire must be used, and it becomes necessary to compromise in order to have neither too large a coil nor too high a resistance with a given number of turns.

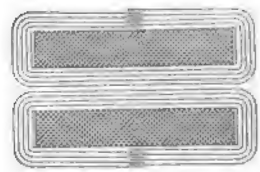


FIG. 12

26. When the key K, Fig. 11, is closed, the inductance of the relay R and of the impedance coil I will act as a barrier to the inrushing current and will prevent it from attaining its maximum strength as quickly as it would if the impedance coil I were not in the circuit. The greater the inductance in the circuit, the slower will the current increase and decrease. Furthermore, the condenser C must be fully charged before the current in the line can reach its maximum value. As fast as the current is able to get through the relay R, it first tends to charge the condenser C, and, as the condenser becomes more and more nearly charged to its full capacity, more current will flow through the coil I, which also impedes its rapid increase. The increase in the strength of the current in the line wire is thus made to take

place more gradually than it would without the condenser and the impedance coil.

On opening the key *K*, the condenser *C* tends to discharge its current through the coil *I* into the line in the direction of the original current and also opposes the discharge from the line, thereby tending to prolong the current in the line and causing it to decrease more gradually. The combination of condensers and impedance coils thus opposes any rapid change in the strength of the current, and the current curve can be made to approach that shown in Fig. 13 by using the proper amount of inductance and capacity.

27. At the rate of twenty-five words a minute, there would be about five dots and spaces, or five curves like the two shown in Fig. 13, a second. The impedance coils and condensers will interfere with telegraphing at a high speed, and especially with rapid automatic telegraph systems, because the signals will be of such short duration that there will not be time for the current to rise or fall through a sufficient range to properly operate the relays. About the lowest audible sound is produced by sixteen complete vibrations per second; therefore, an undulating current that changes at such a low rate that it will not cause the diaphragm of a telephone receiver to move as fast as it will be moved by a current having a frequency of sixteen periods per second, will produce no sound, not even a click, in the receiver.

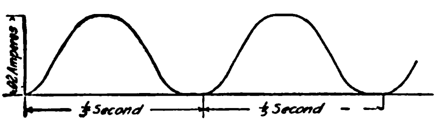


FIG. 18

To make the rise and fall of the telegraph current gradual enough not to affect the telephone receiver, two impedance coils *I*, *I* and two condensers *C*, *C* may be associated with the line circuit as shown in Fig. 14. In order that the telegraph signal made at the sending station shall affect the relay at the receiving station, it is necessary to prevent the flow or leakage of the telegraph current through the receiver. To accomplish this, the condenser C_1 is connected in series

with the telephone receiver TR and the secondary winding s of the telephone induction coil. The condenser will not allow a continuous current to pass through it, because its resistance to such a current is very great. The condenser charges and discharges very slowly when telegraph signals

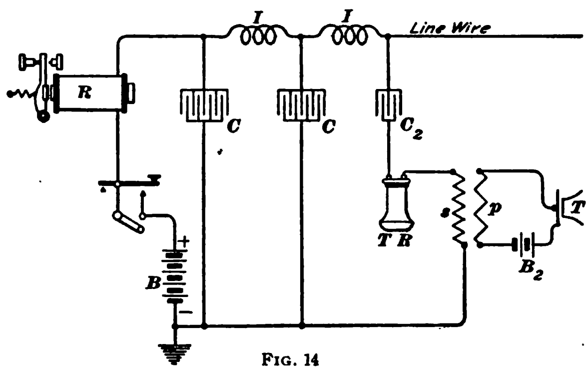


FIG. 14

are being sent, thereby causing the receiver diaphragm to move in and out very slowly, but the rate of change of the current in the receiver is not great enough to cause an audible sound.

28. It has been shown that the telegraph signals, if their rise and fall is gradual enough, do not disturb the telephone receivers. It yet remains to be shown that the telephone current sent from one end will operate the telephone at the other end, but will not interfere with the telegraph signals sent from either end. By talking into a telephone transmitter, an alternating electromotive force is generated in the secondary winding of the induction coil, the average frequency of which is at least 300 periods per second. This rapidly alternating electromotive force will charge and discharge the condenser C_2, thereby producing in the line wire an alternating current similar to that in an ordinary telephone line. Fig. 15 represents such a current wave as might be produced in the line

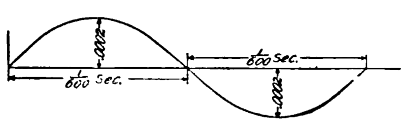


FIG. 15

wire by the simplest sound waves having a frequency of 300 periods per second. Let the curve *A*, Fig. 16, represent the slowly increasing and decreasing telegraph current, and the curve *B* the rapidly alternating telephone current. In the line, these two will be superimposed on each other, producing a resultant curve of the form shown at *C*.

When both the telephone and telegraph are in simultaneous operation, the telegraph current may cause the diaphragm of the receiver to move in and out through a relatively large amplitude, but too slowly to make any sound. At the same time it will vibrate very rapidly through a very small amplitude, because the telegraph current will have its strength very rapidly, but very minutely, increased and decreased by the telephone current. It is enough, nevertheless, to increase and decrease the pull of the magnet on the diaphragm sufficiently to produce sound waves. One vibration is thus superimposed on the other, and the diaphragm vibrates, or trembles, very rapidly as it moves slowly in and out as the telegraph current slowly increases and decreases, and it reproduces the words spoken at the distant transmitter, but the telegraph current produces no sound.

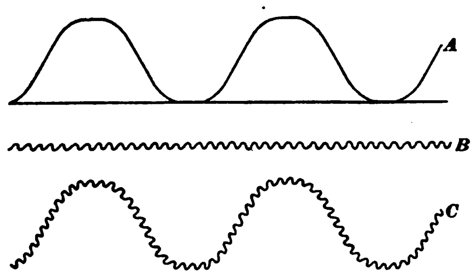


Fig. 16

29. Practically the whole telephone current will go over the line and through the distant receiver, for the reason that a circuit containing inductance offers more opposition to the flow of an alternating current than the simple resistance with which it opposes a direct current, and this opposition increases very rapidly as the frequency increases. For instance, a certain impedance coil, with a resistance of 500 ohms and an inductance of 8 henrys (for a current of .013 ampere), offers an impedance of 15,128 ohms to an alternating current whose

frequency is 300 periods per second. This impedance is over thirty times as large as the simple resistance.

The impedance of a telephone circuit, including a 60-ohm receiver, a 250-ohm secondary coil, and a 2-microfarad condenser, does not exceed about 415 ohms. An induction coil having a lower resistance secondary, such as the 14-ohm coil used by the Bell Companies on their long-distance lines, would be better in this case. In circuit with the impedance coil there is also the telegraph relay, so that the total impedance of a 500-ohm, 8-henry impedance coil, and a 150-ohm, 5-henry telegraph relay at one end of the line circuit is at least fifty times as great as that of one receiver circuit. To insure more satisfactory results, two impedance coils and two condensers may be used at each end, as shown in the *Van Rysselberghe method*, thus compelling practically all the telephone current to pass through the line and the distant telephone circuit.

VAN RYSSELBERGHE METHOD

30. The **Van Rysselberghe method** for the simultaneous transmission of telephone and telegraph messages over the same line was originated and developed by Mr. J. F. Van Rysselberghe, an official of the Belgian telegraph service. The principles just explained are involved in this and all other composite systems.

The complete arrangement of the Van Rysselberghe simultaneous telegraph and telephone system is shown in Fig. 17. It is sometimes advantageous to connect extra condensers C_1, C_4 of 1 or 2 microfarads capacity each around the telegraph keys and relays, as shown by the dotted lines at station *2*. This figure gives a diagram of connections for one complete metallic telephone circuit and two telegraph circuits over one pair of line wires, the ground being used as a return for the two telegraph circuits.

If a completely closed magnetic circuit of good soft iron is used for the impedance coils *I*, enough turns of insulated copper wire to make 50 ohms have been found to be sufficient for each coil. If desirable, an ordinary telephone

annunciator may be used, as shown at D, station 2, in place of the bell shown at station 1, and a push button k may be arranged, as shown at station 2, to short-circuit the secondary winding S of the induction coil while listening. The push button k, which must be released while talking, is not desirable, because, if it is held closed while talking, the person listening at the other end can hear nothing. However, it may improve the working enough to warrant its use.

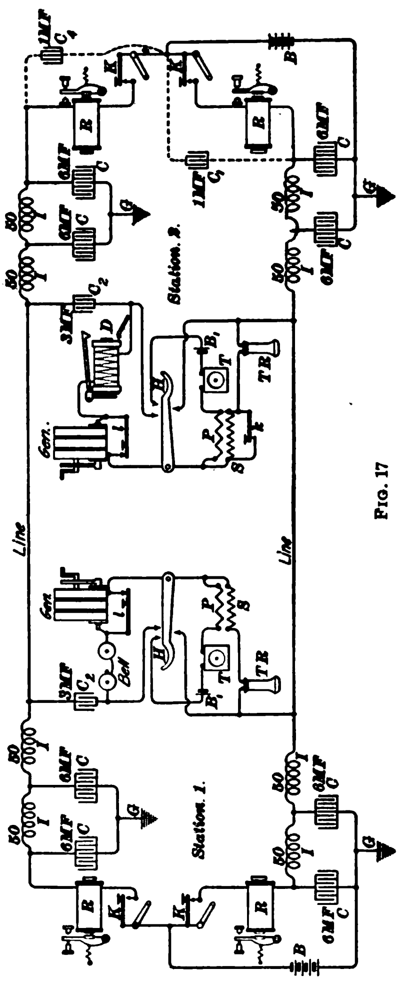


FIG. 17

31. The push button l, which normally short-circuits the generator armature, must be pressed when the generator handle is turned to call up the distant station. Most generators have an automatic device that accomplishes the same purpose when the handle of the generator is turned. When the receiver is on the hook H, the bell and generator are connected across the two line wires through the condenser C_2, the circuit containing the primary winding P of the induction coil, the transmitter T, and the transmitter battery B_1 is open, and the circuit containing the telephone receiver TR and the secondary winding S is short-circuited. When the

receiver is removed from the hook, the bell and generator are short-circuited, the local transmitter circuit is closed, and the short circuit around the receiver and secondary is opened, leaving this latter circuit closed through the condenser C_2 across the two line wires.

32. Telegraph Relays and Batteries.—In almost all simultaneous telephone and telegraph systems, relays of at least 150 ohms resistance should be used, and half the total number of cells necessary for operating the telegraph instruments had better be placed at each end, the two batteries being in series, of course, with each other. When primary batteries are used for operating the ordinary Morse telegraph circuits, gravity Daniell, or Fuller, bichromate cells are generally selected. In some of the long-distance exchanges of the Bell Companies, Fuller bichromate cells are used to supply the current required for all purposes, even when the exchange is so located that storage batteries could be readily maintained. This is done to avoid any possible interruption to the service due to a failure of the source of power used to charge the batteries.

It may sometimes be convenient where the telegraph is not used very much to use the so-called open-circuit telegraph system, in which the relay is connected between the back contact and the battery between the front contact of the telegraph key and the ground. The battery is thus on open circuit except when a dot or dash is being made. In this arrangement, it is necessary to use at each station a battery powerful enough to operate all relays in the same line circuit.

33. Ringing Difficulty.—With the Van Rysselberghe arrangement, it is difficult to ring one telephone bell from the other station, because some of the ringing current, being of low frequency, can flow to ground through the impedance coils and telegraph relay at the same end. Moreover, this current is apt to make the telegraph relay chatter. To avoid this difficulty, it was customary at one time to use one of the two telegraph circuits for signaling purposes. Each

end of one telegraph line would be connected through a relay to ground and a key would be arranged so that, when closed, a battery would be cut in the circuit in place of the relay. The local circuit of the relay at each end would include a drop and the exchange ringing generator. Thus, closing the key at one end would cause the distant relay to attract its armature, thereby closing the circuit containing the drop and the constantly running generator at the distant exchange. The falling of the drop shutter would attract the attention of the operator, who would in the usual way connect her telephone set across the line and reply through it.

34. Over one line wire, it is practical to send simultaneously one telegraph and one telephone message, no second line wire being at all necessary. To do this the following changes should be made in Fig. 17: The two main-line telegraph batteries B, B and the lower ends of the two telephone sets should be directly grounded, and the two lower telegraph sets (one at each end, including the two adjacent impedance coils and the two condensers) and the lower line wire should be omitted.

In composite telephone and telegraph systems, one telephone and two telegraph messages can be sent simultaneously over one pair of line wires, using the earth as a return path only for the two telegraph currents; or, by using the earth as a return for the telephone as well as for the telegraph current, then over a single wire, one telephone and one telegraph message may be transmitted simultaneously. In simplex telephone and telegraph systems, however, the two line wires in parallel are required for one side of one telegraph circuit, the ground forming the other side, and hence only one telegraph and one telephone message can be transmitted simultaneously over two line wires, including the ground as a return for the telegraph circuit.

The difference between the simplex and composite systems lies in the fact that with the former both conductors of the telephone circuit are used in parallel as one conductor, or, as

it is termed, as one Morse wire; while, with the latter, each conductor forms a separate Morse wire. Therefore, with the composite system there are two points to be observed: First, as is the case with the simplex set, the telegraph and telephone currents must not interfere with each other; second, the telegraph current on one of the Morse legs must not interfere with that on the other; or, to use a technical expression, there must be no "cross-writing."

BELL COMPOSITE SET

35. There are many methods of compositing, which are more or less successful, but the American Telephone and Telegraph Company naturally considers the one used by it to be the best. It is illustrated in Fig. 18, in which is shown the apparatus at two exchanges with one pair of line wires connecting them. B, B_1, B_2, B_3 represent the Morse batteries for operating the telegraph circuits, Dc, Dc_1, Dc_2, Dc_3, differentially connected retardation coils, and Sc, Sc_1, Sc_2, Sc_3 series-connected retardation coils. The connections at the two terminal stations are identical, except that opposite terminals of the Morse batteries are grounded. If storage batteries are used, one battery at each end connected in the ground taps go and $g'o'$, or one battery connected in either ground tap go or $g'o'$, may serve both telegraph circuits.

36. Each differentially connected retardation coil Dc, Dc_1, Dc_2, Dc_3 consists of two windings, the total resistance of which is 50 ohms. The two windings are differentially connected so that a current flowing through the two windings tends to magnetize the one iron core, on which they are placed, in opposite directions; hence it is called a *differentially connected coil.* Each series-connected retardation coil consists of two windings having a total resistance of 30 ohms and connected so that both windings tend to magnetize the one core in the same direction; hence it is called a *series-connected coil.* When a direct current passes through a differentially connected coil, the magnetizing effect of one winding

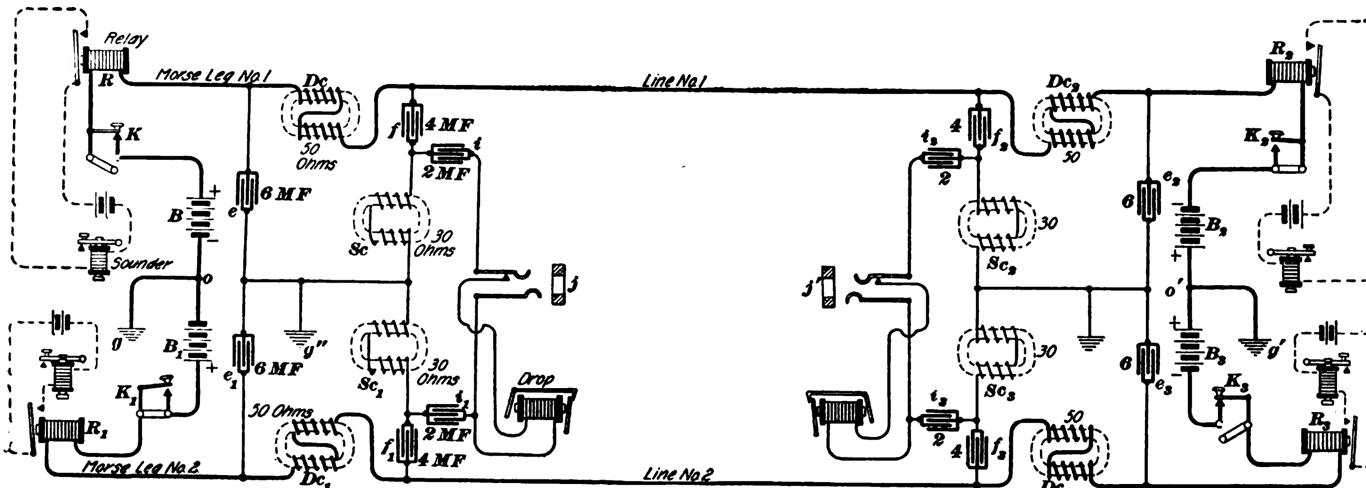

Relay
R
K
Morse Leg No.1
Dc
50 Ohms
B
+
−
e
6 MF
Sounder
o
0
B1
K1
R1
e1
6 MF
g″
Morse Leg No.2
50 Ohms
Dc1
f
4 MF
i
2 MF
Sc
30 Ohms
Sc1
30 Ohms
i1
2 MF
f1
4 MF
j
Drop
Line No.1
Line No.2
j′
i2
2
4
f2
Sc2
30
Sc3
30
i3
2
4
f3
Dc2
50
Dc3
50
6
e2
B2
o′
B3
e3
6
g′
R2
K2
K3
R3

Fig. 18

neutralizes that of the other winding, hence the coil, if evenly balanced, possesses no inductance, and this is true for a direct current even if interrupted at the highest frequency existing in manual telegraphy, that is, when dots are being sent by hand in rapid succession. Even if the two windings are not exactly balanced, the impedance will be but little greater than their resistance because the frequency of the telegraph current is low. This method of connecting the coil is necessary in the telegraph circuit, because sluggish working of telegraph instruments, due to a high inductance in series with the telegraph apparatus, is very noticeable to a telegraph operator.

But for the high-frequency voice currents of small strength, the large and massive iron core seems to act in a sluggish manner, which prevents a complete change of its magnetism throughout the whole core; in fact, the two windings act practically as two independent retardation coils with open magnetic circuits connected in series, offering, therefore, a maximum impedance to such currents.

37. Operation.—If the operator at key K, Fig. 18, is sending, a pulsating current of low frequency will flow from B through K–relay R–Morse Leg *No. 1* to the coil Dc. The sharp points of the current curve will be rounded off, that is, the current will be more like a smooth sine curve, as a result of the inductance of Dc and the capacity of the condenser e. The current that passes through Dc, being of low frequency, will follow line *1* and operate the distant Morse relay R_2. Should any of the impulse pass through the condenser f, it will pass to earth through the retardation coil Sc, and be kept out of the telephone circuit by the condenser i.

Cross-writing would result if a Morse current passed from conductor *1* to *2*; but this is prevented by the presence of the grounded condensers e, e_1, e_2, e_3. Every time the Morse key is closed or opened, there is an induced current due to the self-induction of the various coils; the induced kicks due to the relay R and one end of coil Dc are shunted to ground

through, or absorbed by, the condenser *e*, while the kick from the other end of Dc may pass to ground through, or be absorbed by, the condenser *f* and the coil Sc. The coil Sc is said to be a frequency sieve because it allows the rapid inductive kicks to pass through it and thus prevents the telephone receiver from being affected, but the voice currents of very much greater frequency cannot pass through it. Practically all disturbing noises are thus shunted around the telephone, which is therefore quiet.

It is sometimes advisable in some composite and simplex systems to bridge the telegraph key with a 2-microfarad condenser; it absorbs the kick due to the self-induction of the relay coil when the circuit is broken by the telegraph key, thus reducing the sharp fluctuation in the line that tends to produce a disturbance in the telephone set.

38. Turning now to the telephone circuit in Fig. 18, it will be seen that the telephone current flows into the jack *j*, and, being of high frequency, readily passes through the condensers i, i_1, but is prevented from flowing through the coils Sc, Sc_1 by their high impedance. It then passes through the condensers f, f_1, but is kept out of the Morse legs by the impedance of the coils Dc, Dc_1, and so flows out on the line to the distant exchange. Here, again, it is kept out of the Morse legs by the coils Dc_2, Dc_3, but flows through the condensers f_2, f_3 and i_2, i_3 to the jack j'.

The greater the capacity of a condenser within certain limits, the more efficient it is for transmitting voice currents, but experience shows that if too large condensers are used at i, i_1, i_2, i_3, a perceptible disturbance is produced by the telegraph current in the telephone, due to the larger charge and discharge currents in these condensers, as the potential in the telegraph line rises and falls when a telegraph key is opened and closed.

Thus the Morse current is kept out of the telephone circuit; the Morse current from one leg cannot reach the other leg; and the telephone current is prevented from flowing through the Morse legs.

39. Coils.—A Western Electric 50-ohm differentially connected coil is shown in Fig. 19. It is wound with No. 20 single cotton-covered wire. A 30-ohm series-connected coil is made in the same style and with the same dimensions, but is wound with No. 18 single cotton-covered wire and has clips *b*, *c* connected together instead of *b*, *d*. The core *e* consists of a bundle of iron wires, about No. 25 B. & S., from $1\frac{1}{2}$ to 2 inches thick. The coils are wound on wooden spools; the bundle of iron wires is bent in the form of a **U** and passed through the spools, and the ends are interlaced and tied with iron binding wire.

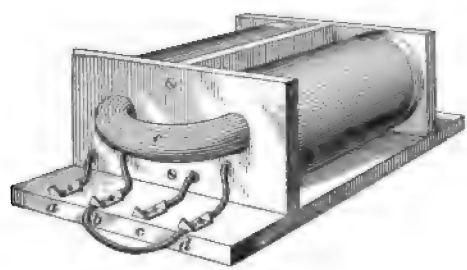


FIG. 19

40. One defect of the composite set lies in the fact that, there being so much capacity to ground through the condensers e, e_1, e_2, e_3, Fig. 18, these condensers must be charged before the current will flow out on the line. To use the language of the telegraph operator, this results in a *heavy line*, by which he means that the sounder does not respond instantly to the touch of the key. This condition is somewhat bothersome when fast sending is being done, but, for general use, the composite circuit is successful, and is able to compete with the straight Morse circuits, such as are used by the Western Union Company. A minor defect is that the ordinary ringing-current generator cannot be used, because the current it produces is sufficiently low in frequency to pass through the coils Dc, Dc_1, Dc_2, Dc_3 and to interfere with the proper working of the Morse instruments; this difficulty is overcome by the use of composite ringing apparatus. The drops shown in Fig. 18 may be replaced by relays which are more sensitive and which may be used to close circuits containing drops or lamps.

COMPOSITE RINGING APPARATUS

41. An approved type of **composite ringing circuit and apparatus** used by the Bell Telephone Companies is shown in Fig. 20. The drop side of the toll line is connected to the spring contacts of a relay *F*, and when this relay is not energized, the circuit is closed through the outer contact points of the relays *F* and *R* to the line side; this is the condition during conversation. Should the operator wish to call the distant office, a plug is inserted in the jack and the regular ringing key is depressed in the usual manner, sending the generator current to the points *o*, *o'* where a shunt circuit is formed through the condenser *N* and the relay *L*. This relay, which is designed so that a low-frequency alternating current, such as furnished by an ordinary ringing generator, will operate it, is thereby energized, and its grounded armature is drawn up against the contact point *a*, thereby completing a circuit from *g* through the battery *B* and relays *M*, *R* and contact *a* to *g'*, and energizing both the relays. The closing of the relay *M* completes a circuit containing the

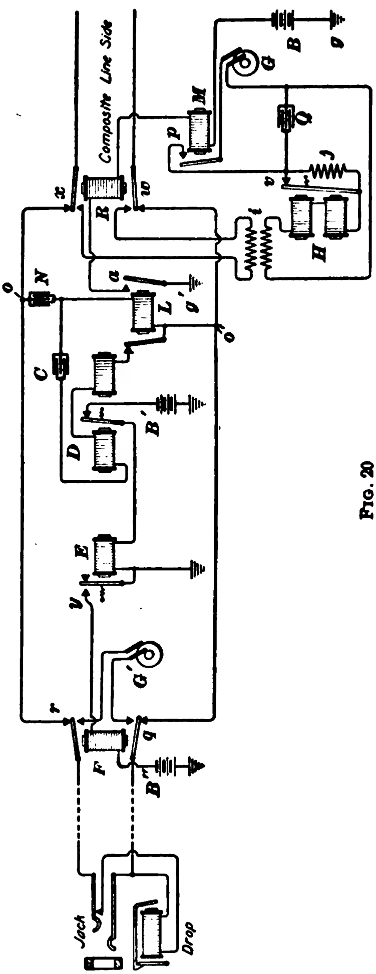


Fig. 20

ringing generator *G*, one winding of the repeating coil *i*, and a specially designed interrupter *H*, the vibrating armature of which is shunted by a 1,000-ohm non-inductive resistance *j*. As long as the circuit remains closed at *p*, the armature of *H* will vibrate. The closing of the relay *R* connects the secondary winding of *i* across the line.

The action of *H*, starting with it energized and the vibrator making contact at *v*, is as follows: The alternating current from *G* energizes *H* and the circuit is opened at *v*, thereby connecting the resistance *j* in series with *H* and reducing the current so much as to cause *H* to release its armature, thus closing the circuit again at *v*, in which position the resistance *j* is short-circuited. This operation continues as long as the circuit remains closed at *p*. The non-inductive resistance *j* connected around the contact *v* reduces the sparking at *v* without interfering with the operation of the vibrating magnet *H*. The vibrator is so constructed that about twenty interruptions or pulsations are produced for each cycle or period of the alternating current; hence, the frequency of this current becomes twenty times that of the alternator. This high-frequency current produces, by induction through *i*, a current of similar frequency that flows through the line, but does not interfere with the Morse working. The condenser *Q* is used to form a path for the high-frequency discharge from the magnet *H* and thus keep it out of the generator *G*.

42. Suppose that Fig. 20 now represents the connections at the receiving office; the high-frequency current coming from the distant office passes through the springs and outer contacts *w*, *x* of the relay *R* to the points *o*, *o'*. From *o*, this current passes through the condenser *N*. The relay *L* has enough inductance to prevent sufficient of this high-frequency current from flowing through and operating it, but it can pass through the condenser *C* and the relay *D* to the point *o'*, thereby causing the relay *D*, which is especially designed so that this high-frequency current will cause it to attract its armature, to open the circuit containing the battery *B'* and relay *E*. Consequently, the relay *E* releases its armature,

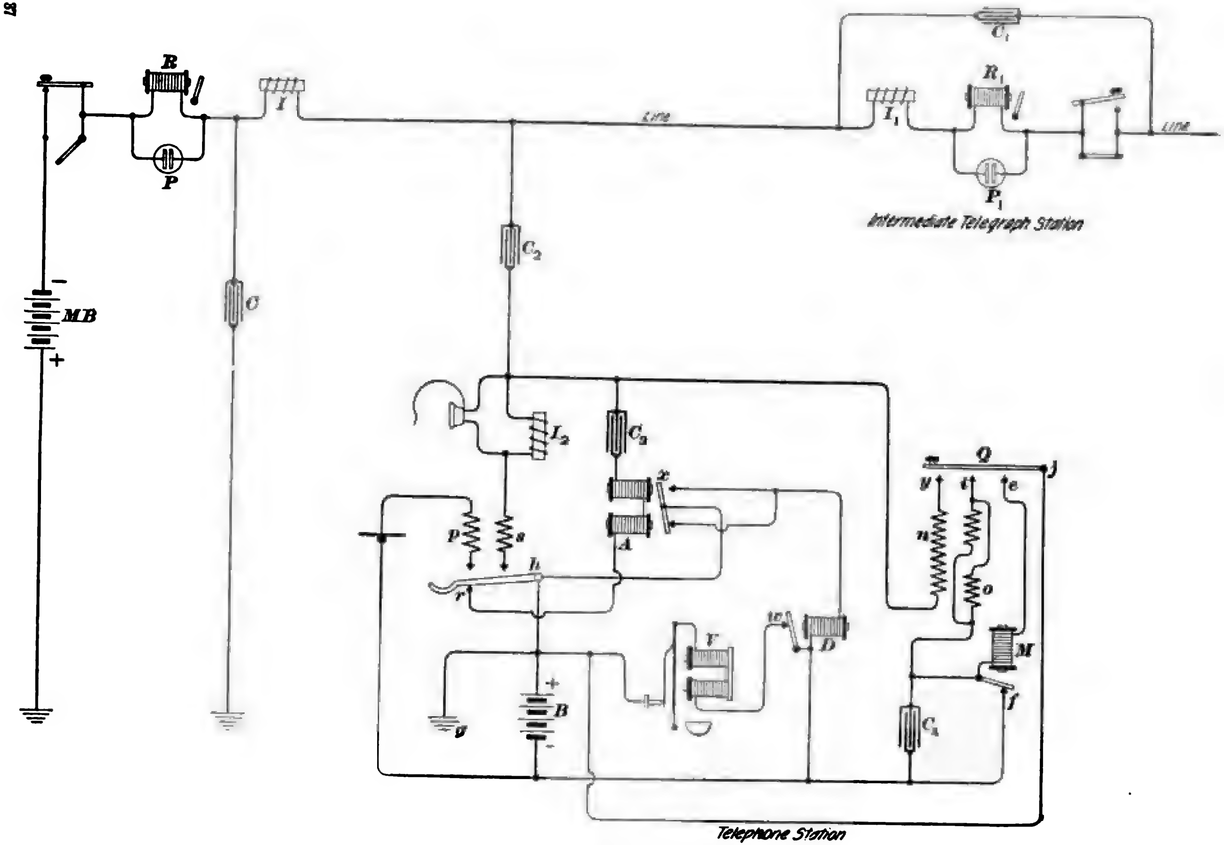
thereby closing at y the circuit containing the relay F and battery B. The relay F then attracts its armature and thus connects the ringing generator G' across the drop side of the composite set, which causes the drop to operate. The Morse apparatus being cut off at contacts q, r, which are now open, the current from G cannot affect its working.

43. While the composite ringer seems like a very complicated piece of wiring, it is really only a buzzer-like contrivance arranged to furnish a current that has too high a frequency and too small an amplitude to affect the Morse instruments, while the delicate 150-ohm polarized relay D barely responds to these rapid impulses. It will probably be but a short time until this composite ringer will be replaced by an alternating current of a frequency of from 125 to 150 cycles to be generated by a special generator, so that to ring on a composited circuit an operator will simply push a special ringing key. All that will be left of the composite ringer will be possibly the 150-ohm polarized relay D, though it now seems probable that this will also be replaced by a more effective one.

In offices not supplied with a generator, a number of dry cells, though preferably Leclanché cells, connected in series with the primary of an induction coil and a stiff-springed, closely adjusted buzzer, serve the purpose of producing the high-frequency current; but the current from the secondary, of course, is alternating and of much higher voltage than that of the cells in the primary. With a properly designed line drop or relay, it is said that a 133-cycle or even a 60-cycle alternating current may be used for signaling without interfering with the telegraph service.

CANADIAN PACIFIC COMPOSITE SYSTEM

44. A composite system used by the Canadian Pacific Railway on some of its telegraph lines is shown in Fig. 21. One terminal and one intermediate telegraph station and one telephone station only are shown. The right-hand end of the line would be equipped with terminal telegraph and



R
P
MB
I
C
C1
R1
I1
P1
Line
Line
Intermediate Telegraph Station
C2
I2
C3
x
A
p
s
h
r
B
g
V
w
D
Q
j
y
t
e
n
o
M
f
C4
Telephone Station

FIG. 21

telephone stations as shown for one end only. There may also be intermediate telephone stations at any point along the line. Only the features peculiar to this equipment will be explained. In general, it is said to be usually possible to operate this system successfully over an ordinary telegraph line 100 miles in length and have five intermediate stations.

Each telegraph relay is shunted by a so-called polarization cell P, which may consist of lead plates in very dilute sulphuric acid. The polarization cells offer such great opposition to the passage of the direct telegraph currents that their presence does not in the least interfere with telegraph signaling. At the same time, they serve as a shunt for any telephone signaling current that might pass through the impedance coils I, I_1. Intermediate telegraph stations are bridged by a condenser C_1 to allow the voice currents to readily pass.

45. The telephone is an ordinary local-battery instrument with special signal-receiving and signal-sending apparatus. An especially powerful transmitter is used and a local battery B consisting of five to seven Edison-Lalande cells. The receiver is shunted by an impedance coil I_2 having a movable iron core by means of which the impedance may be considerably varied. The impedance is adjusted as high as is consistent with the necessary freedom from disturbing noises. Thus by powerful transmission and less sensitive receivers the bad effect of disturbing noises is reduced.

46. To signal a distant telephone station, the push button Q is pressed; a rapidly interrupted current then flows from $+B$ through $j-\begin{Bmatrix} e-M \\ i-o \end{Bmatrix}-f$ to $-B$. The condenser C_2 reduces the sparking at the contact point f and probably makes the current through the primary winding o of the repeating coil smoother. This current is interrupted at such a rapid rate by the relay M that the current induced by the primary winding (which consists of two coils connected in parallel) in the secondary winding n is too high in frequency

to disturb the telegraph relays. This high-frequency alternating current flows from n through C_2–line–distant telephone–ground–g–j–y–n. On account of the high impedance of I_1, most of this signaling current will flow through C_1; what does pass through I_1 will pass through the polarization cell P_1 and around the relay R_1. The impedance coil I, condenser C, and polarization cell P will likewise protect the relay R. Hence the signaling current will not disturb the operation of the telegraph relays.

Such a current coming from a distant telephone will flow from the line through C_2–C_3–polarized relay A–r–h–g. This will cause the armature of the polarized relay A, which resembles a biased polarized bell, to vibrate very rapidly in unison with the high-frequency signaling current through its coils. As a result, the circuit through the winding of the slow-acting relay D is held open such a large part of the time that the armature of D, not being able to vibrate as rapidly as that of A, remains against its back stop w as long as x continues to vibrate, and thus allows current from B to flow through and ring the ordinary vibrating bell V.

This signaling circuit is rather complicated and current flows from B through D all the time, except when Q is actually closed while signaling a distant telephone, or an incoming current causes the armature of relay A to vibrate.

OPEN-CIRCUIT TELEGRAPH SYSTEM

47. In Fig. 22 is shown a simple composite system, described by Louis Muhlheizer in the American Telephone Journal, with the telegraph apparatus arranged in what is called the **open-circuit telegraph**, or **Morse, system.** That is, the telegraph batteries B_1, B_2, B_3, B_4 are normally on open circuit, being connected between the ground and the front stop of the telegraph keys K_1, K_2, K_3, K_4, while the telegraph relays are connected between the ground and the back stop of the keys. Each telegraph set must be provided with similar batteries B_1, B_2, B_3, B_4 of about 150 volts each where 150-ohm relays are used on a line about 100 miles long.

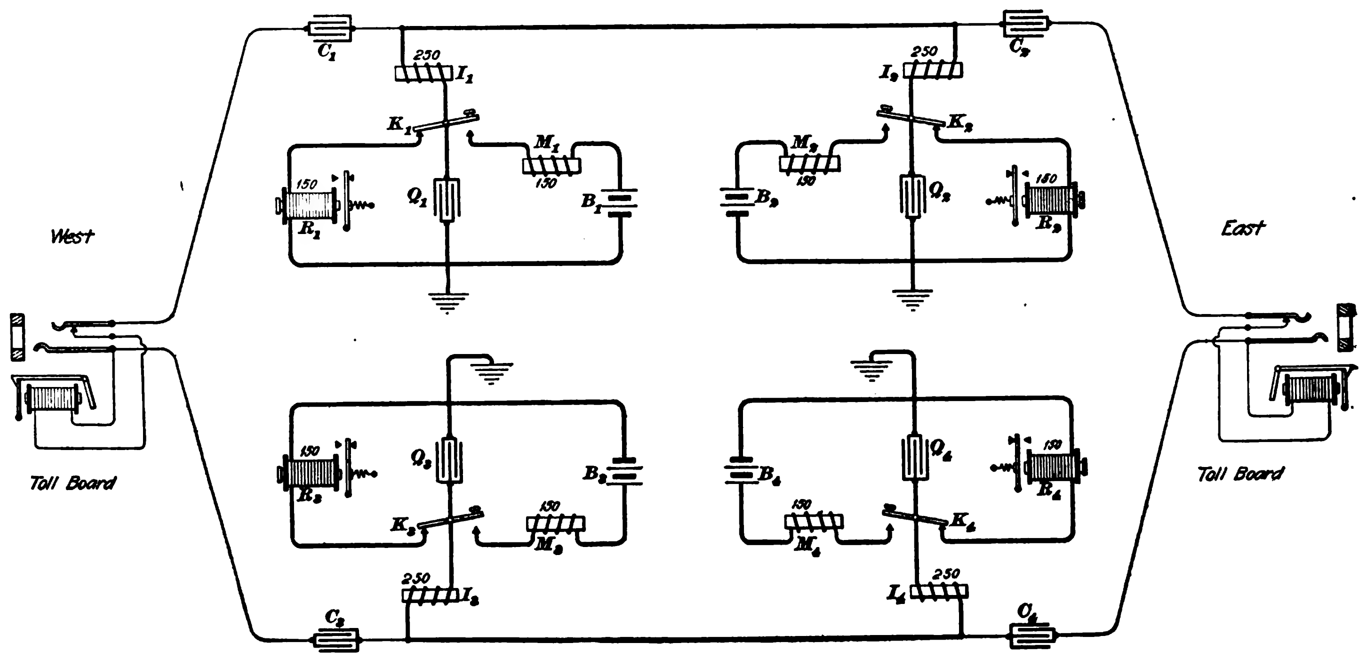

West
East
Toll Board
Toll Board
C_1
C_2
C_3
C_4
250
I_1
I_2
I_3
I_4
K_1
K_2
K_3
K_4
M_1
M_2
M_3
M_4
150
Q_1
Q_2
Q_3
Q_4
B_1
B_2
B_3
B_4
R_1
R_2
R_3
R_4

FIG. 22

Closing the telegraph key K_1 cuts out the relay R_1 and cuts in the battery B_1 and the impedance coil M_1, thus closing the distant relay R_2. Normally, no telegraph battery is connected to either line wire and the circuit is very evenly balanced at all times; thus the circuit is free from disturbing noises.

The condensers Q_1, Q_2, Q_3, Q_4 reduce the sparking at the telegraph keys and the resulting disturbance that it would produce, while the condensers C_1, C_2, C_3, C_4 are necessary to separate the telephone and telegraph circuits. The impedance coils I_1, I_2, I_3, I_4 are constructed with a core of No. 24 soft-iron wires $\frac{1}{2}$ inch in diameter and $4\frac{1}{2}$ inches long, wound with No. 30 B. & S. silk- and cotton-covered copper wire to a resistance of 250 ohms. The impedance coils M_1, M_2, M_3, M_4 are similarly constructed, except that they are wound to a resistance of 150 ohms, the same resistance as the relays R_1, R_2, R_3, R_4.

48. This open-circuit Morse system is said to be fully as good as a repeating-coil simplex system, which gives only one whereas this gives two telegraph circuits. Although this circuit must be very carefully maintained to prevent the occurrence of tree grounds or other sources of leakage due to low insulation, it is believed to be as little affected by these troubles as a repeating-coil simplex circuit. In wet weather, the only difficulty noted is the necessity of occasionally adjusting a relay. This circuit is not adapted to a high-speed telegraphic transmission, on account of the retarding effect of the various coils, but it is useful on toll lines up to 100 miles in length and produces practically no interference with the telephonic transmission. The ringing is also satisfactory, provided that an ungrounded generator is used.

SIMULTANEOUS TELEPHONY AND TELEGRAPHY

(PART 2)

DUPLEX AND MULTIPLEX TELEPHONY

1. An arrangement of apparatus whereby two telephone conversations may be held over the same pair of wires at the same time is termed **duplex telephony.** An arrangement of apparatus whereby three telephone conversations may be held simultaneously over two pair of line wires is termed **multiplex telephony.** For duplex telephony, the circuits are arranged in about the same manner as in simplex telephone and telegraph systems, telephone instruments being substituted for the telegraph apparatus. Duplex and multiplex telephony will be considered together since they depend on similar principles.

IMPEDANCE-COIL METHOD

2. Two Circuits Over One Pair of Wires and Ground.—In Fig. 1 is shown a duplex telephone system using impedance coils *c d* and *e f* across one pair of telephone line wires. The two windings *c v* and *v d* are wound on the same iron core and constitute one impedance coil. Similarly, *e u* and *u f* form one impedance coil. The telephone instrument *A* uses a metallic circuit and is terminated at the exchange in jack *J a* and drop *D a*, while *B*, which uses the two wires in parallel as one conductor and the ground as the return conductor, terminates in the

exchange at jack *J b* and drop *D b*. Current from *A* flows over line wires *1* and *2* in series while current from *B* flows over the two wires in parallel and hence produces no difference of potential between points *c*, *d* or *e*, *f*, and there is very little tendency for any telephone current from *A* to flow through *c d* or through *d–v–B*–ground–*D b–J b–u–e–c–A* on account of the high inductance of even one-half of each impedance coil. Each impedance coil should have a complete iron circuit and enough turns to give a very high inductance. For this purpose, 600- or 1,000-ohm impedance coils may be used. The longer the line, that is, the greater

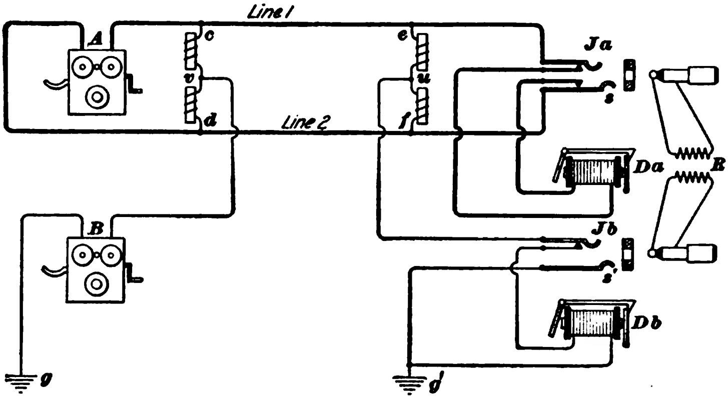


FIG. 1

its resistance, the greater should be the inductance of the impedance coils. The circuit $B\text{–}v\text{–}\left\{\begin{matrix} c\text{–}e \\ d\text{–}f \end{matrix}\right\}\text{–}u\text{–}D\,b\text{–}g'\text{–}g$ is called a **phantom circuit,** because it is an extra circuit obtained without the actual addition of any more line wires than were already in use for the circuit containing the telephone *A*.

3. Three Circuits Over Two Pair of Wires.—An objection to all duplex telephone circuits using the ground as part of one circuit is the difficulty of keeping the two sides of a metallic circuit evenly balanced and free from grounds, so that the two telephone circuits will be reasonably quiet—that is, free from noises due to induction and leakage. For this reason, it is usually more satisfactory to

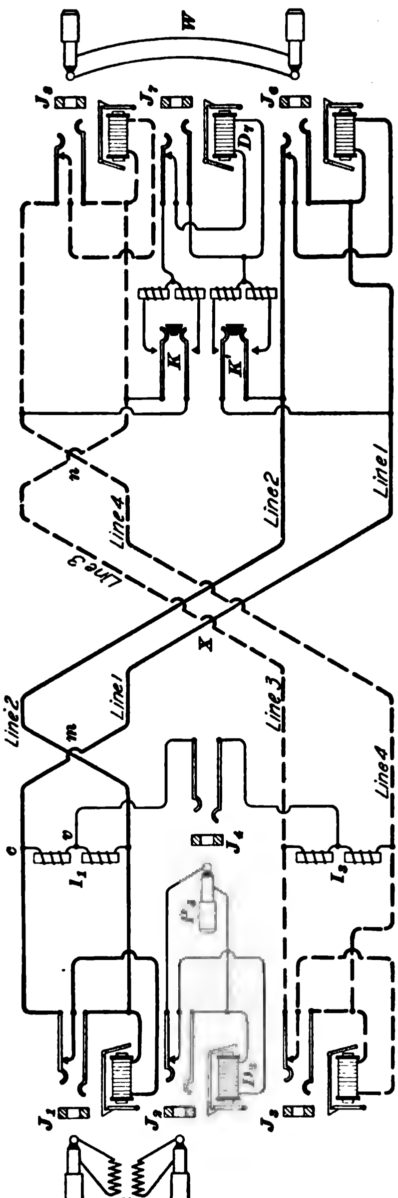


FIG. 2

arrange two complete metallic circuits, as shown in Fig. 2, so as to obtain three telephone circuits.

The third circuit may be brought through a jack J_4 and plug P_4 to the jack J_2 and drop D_2, or two keys K, K', may be used to connect the impedance coils across the two line circuits. To use the third, or phantom, circuit, the plug P_4 must be inserted in the jack J_4 and the keys K, K' must be closed. Whichever arrangement is the more convenient may be used, although the two-key arrangement has the advantage of leaving the two pair of line wires free of even the impedance coils when the phantom circuit is not in use.

The line wires constituting the metallic circuits should be transposed, as indicated at m, n, as would any two pair of parallel and adjacent telephone line wires, to eliminate cross-talk between the

two pair. Furthermore, one pair of wires should be transposed with respect to the other pair, as shown at *X*, in order to eliminate cross-talk between the phantom circuit and any other circuit parallel and adjacent but not associated with this duplex circuit.

To avoid cross-talk and other disturbances, it is essential that each impedance coil should have two halves of equal resistance and especially of equal impedance to voice currents; the impedance of the two halves should not differ by

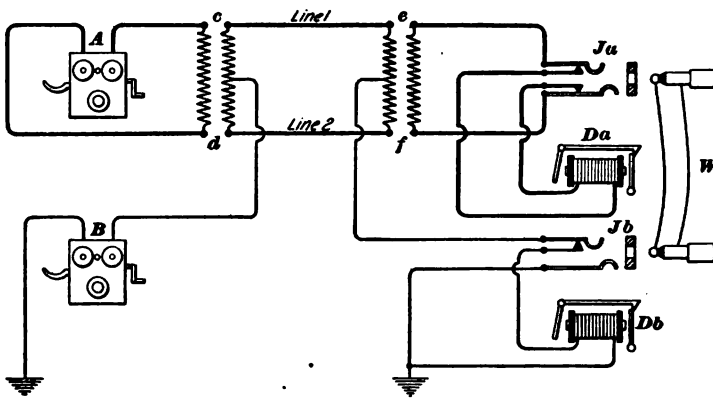


FIG. 3

over one-half of 1 per cent. Each complete impedance coil should consist of four windings so connected as to form two coils of equal resistance and the same number of turns.

REPEATING-COIL METHOD

4. In Fig. 3 is shown a duplex telephone system using repeating coils *c d* and *e f* across one pair of telephone line wires. The ground is used as a return for the phantom circuit containing the telephone *B*. *Ja* and *Da* are the jack and drop, respectively, for telephone *A*, and *Jb* and *Db* for telephone *B*.

Three telephone circuits may be obtained over two pair of line wires by the arrangement shown in Fig. 4. This

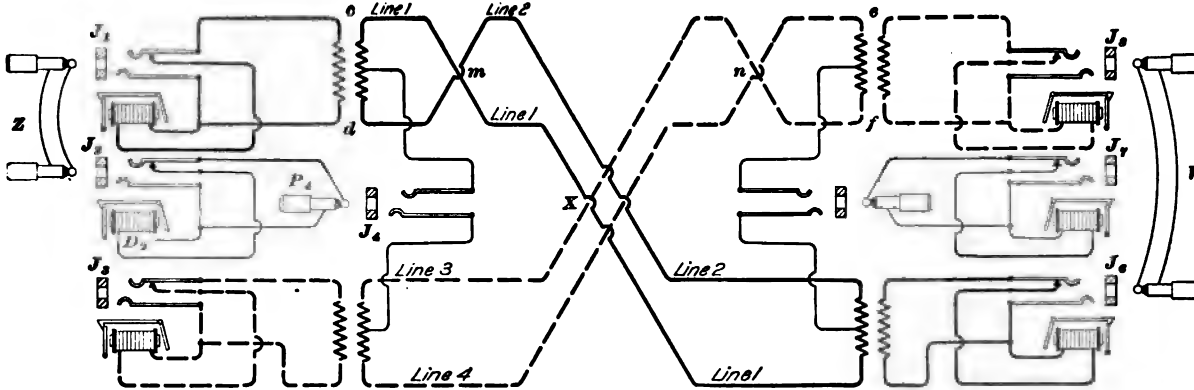

Z
J1
J2
J3
J4
P4
D2
o
d
Line 1
Line 2
m
Line 1
X
Line 3
Line 4
Line 2
Line 1
n
e
f
J8
J7
J6
W

FIG. 4

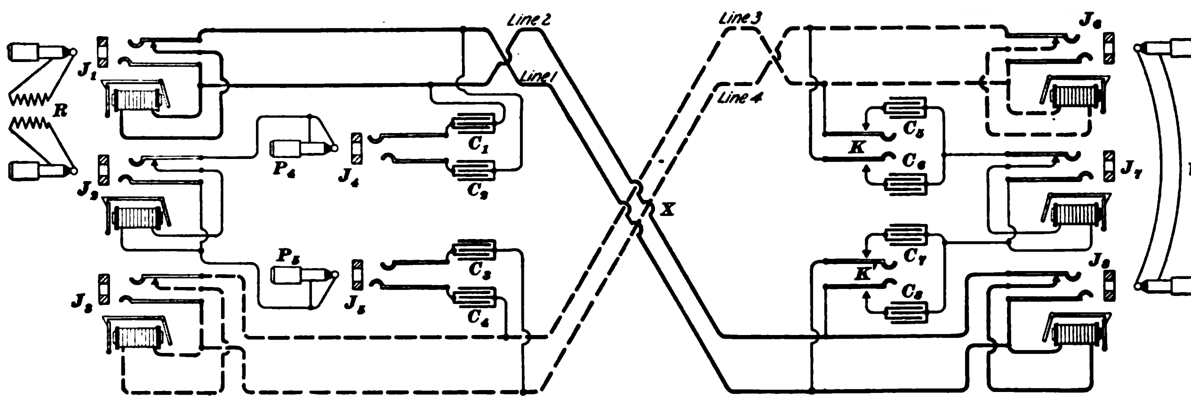

R
J1
J2
J3
P4
P5
J4
J5
C1
C2
C3
C4
Line 2
Line 1
X
Line 3
Line 4
K
K
C5
C6
C7
C8
J6
J7
J8
W

FIG. 5

method is not as efficient as the impedance-coil arrangement. These duplex telephone systems so closely resemble the simplex telephone and telegraph system using repeating coils, which was explained in *Simultaneous Telephony and Telegraphy*, Part 1, that no further comment seems necessary.

CONDENSER METHOD

5. It has been suggested that condensers C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8 may be used, as shown in Fig. 5, for obtaining three telephone circuits from two pair of line wires. The condenser should be of rather small capacity, say about $\frac{1}{2}$ microfarad.

Either the arrangement of jacks J_4, J_5 and plugs P_4, P_5 shown at the left-hand end of the circuit, or the arrangement of keys K, K' shown at the right-hand end of the circuit may be used. Although the same conductor is connected to both the tip and sleeve of one plug P_4 or P_5, it is necessary to use these double contact plugs and jacks P_4, P_5, J_4, J_5, or the keys K, K' in order not to leave two condensers bridged across each pair of line wires when the phantom circuit is not in use. The ground and one condenser at each end could be substituted for one metallic circuit and the two corresponding condensers here connected to it at each end; such an arrangement would give two telephone circuits with one pair of line wires and the ground. Either the impedance-coil or the repeating-coil method is superior to the condenser method.

Some companies make coils that they call **duplexers.** They are simply repeating or impedance coils mounted in suitable boxes and provided with the necessary number of binding post terminals. Sometimes a movable arm is provided so that the middle connection to the winding may be moved to various points along the winding until the circuit is properly balanced; allowance can sometimes be made in this manner for a circuit whose two sides are not well balanced.

PHANTOM CORD CIRCUITS

6. Where phantom circuits are obtained by the use of impedance coils, as in Figs. 1 and 2, a cord circuit containing a repeating coil should be employed to connect a telephone on a phantom circuit with a telephone on the metallic circuit from which that particular phantom circuit is derived. Otherwise, the half, for example *c v*, Fig. 2, of the impedance coil connected to one side of one metallic circuit will be short-circuited while the other side of the same metallic circuit, for example line wire *2*, will be connected directly to the ground, in Fig. 1, or in Fig. 2, to the middle of the impedance coil I_3 across the other metallic circuit. In either case, the sounds heard in one telephone due to talking in the other, would be due mostly to a large amount of cross-talk caused by a badly unbalanced circuit.

Cords containing repeating coils *R*, Fig. 5, should also be used to connect a telephone on a phantom circuit, obtained by means of condensers, to a telephone across either of the metallic circuits. To connect the circuits terminating in jacks J_4, J_5, Figs. 2 and 3, a cord circuit *W* without a repeating coil may be used. Generally, repeating coils should not be inserted in cord circuits *W*, *Z*, Figs. 3 and 4, used in duplex systems obtained by means of repeating coils.

TROUBLES ON DUPLEX AND SIMPLEX CIRCUITS

7. The two wires composing a pair used in a duplex or simplex system must be of equal resistance, inductance, and capacity to give a quiet telephone circuit. Generally, the inductance and capacity will be sufficiently equal to cause no trouble if the resistances are equal. If one side of a line should have a loose connection, its resistance may be increased enough to cause cross-talk between the telephone circuits on a duplex telephone system and to cause the telegraph click to be heard in the telephone circuit on a simplex telephone and telegraph system. Should the connections be very loose, the ringing current will cause the telegraph relays to chatter

badly. A partial or total ground will produce the same troubles.

Short circuits between the two wires constituting a pair interfere only with the telephone transmission over that pair, they do not injuriously affect the transmission over the phantom circuit.

8. Duplex circuits should be provided with lightning arresters at all instruments and terminals to prevent as much as possible the tendency of lightning to pass through and damage the impedance repeater coils or condensers on its way to the ground. To avoid cross-talk with other metallic lines, the two pair used in a duplex circuit must be transposed, as shown at x, Figs. 2, 4, and 5, in addition to the regular transpositions between the two wires of each pair.

Where a pair of wires forming a metallic circuit, duplexed by means of impedance coils, is connected through an exchange with a grounded circuit, a repeating coil should be used in the cord circuit, otherwise the system will act as if grounded on one side. No repeating coil is necessary, however, in connecting a grounded circuit to the grounded portion of a phantom circuit.

It is essential for good service that the metallic circuits used in duplex or simplex systems be kept in good condition; there will then be no more trouble on such systems than there would be with two regular independent circuits.

SWITCHBOARDS FOR COMPOSITE AND SIMPLEX SYSTEMS

TEST AND MORSE BOARDS

TEST PANELS

9. The business done by the Bell Long-Distance Company is distinctively a toll business, and, therefore, the lines owned by this company are toll lines. Compared with the lines handled by a local company, these circuits are few in number; an office in which two hundred of these lines are operated is very large. These lines have also another peculiar feature in that they contain among their number, wires that are leased for telegraph, or so-called Morse, purposes. From these considerations, it is necessary that the line terminals should be so constructed and wired that access can be had to them instantly, so that in the event of one of the leased wires failing, it can be quickly replaced by another. Certain sections of a **test and Morse board**, which is located in the wire chief's office are called **test panels**; each panel consists of a vertical slab of hard rubber mounted in a framework of wood and equipped with four to six rows of standard three-point jacks. The number of horizontal rows of jacks depends on the size of the office, the number of lines, etc. The standard board may have any number of horizontal rows up to forty-one.

Two classes of lines enter the test board—one, the so-called *subscriber loop*, runs from the subscriber switchboard to the subscriber station; the other, the *toll line*, runs from the toll switchboard to some other long-distance office. These lines must be so wired that they may be readily connected to the necessary apparatus provided for simultaneous telegraphy

and telephony. The two systems used for this purpose are the *composite* and the *simplex*, and the apparatus required by each is called a composite set, or a simplex set, as the case may be. In wiring a test board, therefore, the terminals of the subscriber loop, the toll line, and the composite or simplex set are brought independently to jacks in the test board, so that by making the proper cross-connections at this point the complete circuit may be cut through.

10. In Fig. 6 is shown the wiring of a subscriber loop

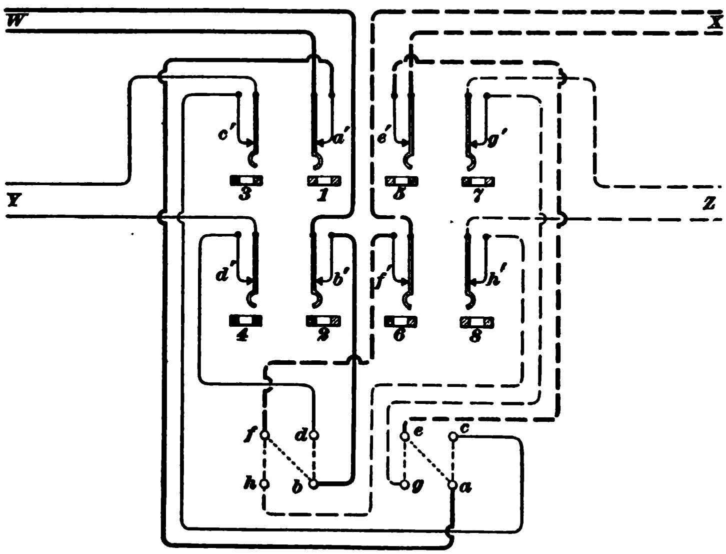


Fig. 6

through the test board. The subscriber loop is shown at *W* coming from the subscriber's station, and, after being cross-connected at the main distributing board, is carried through the two cut-off jacks *1*, *2* on the test board to the lugs *a*, *b* on a small connecting rack placed in the rear of the board. If a direct telephone circuit is desired, without Morse, the cross-connection is that shown by the dotted lines *a e* and *b f*. From *e*, *f*, the circuit runs to the cut-off jacks *5*, *6*, respectively, and then along wires *X* to the drop and answering jack on the subscriber board. Should the use of a composite set be

required, *a* is connected to *c*, *g* to *e*, *b* to *d*, and *h* to *f*, as indicated by the short-dash lines, instead of connecting *b* to *f* and *a* to *e*. In this case, the line runs from the lug *b* through *d*, thence through the cut-off jack *4* to the line side *Y* of the composite set; returning, it passes through the cut-off jack *3*, lugs *c*, *a*, and jack *1*, back to the subscriber's line *W*. The drop side *Z* of the composite set, which runs to the switchboard, passes through jacks *7* and *8* to the lugs *g* and *h*, respectively, thence through cross-connections *g e* and *h f* and jacks *5* and *6*, respectively, to a drop and answering jack across wires *X*.

The line is composited by merely cutting through the proper cross-connections at the back of the board. The cut-off jacks afford a means of testing various portions of the line, by isolating them for the time being from the remainder of the circuit. When a plug is inserted in a jack, it makes contact only with one spring, the plug not going in far enough to touch the contact point on which the spring normally rests. This contact point is called the **normal contact** of the jack.

11. If plugs are placed in jacks *1* and *2*, the line *W* may be tested toward the subscriber station, the remaining portions being cut off; while if plugs are placed in jacks *5* and *6*, the test may be made toward the switchboard on wires *X*, the remainder of the circuit being cut off. The composite set may be cut out by twin plugs placed horizontally so as to connect the springs of jacks *1* and *5* and *2* and *6*. By inserting twin plugs vertically in jacks *3* and *4*, the line *W* is opened; twin plugs inserted vertically in jacks *1* and *2* cross the line wires *W*, that is, connect the two sides together. These connections are merely an elaboration of the circuits used by the wire chief in a local office for testing in and out, and which runs to the main distributing board. In some boards, there are no lugs *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, but a' is permanently connected to c', b' to d', g' to e', and h' to f'; this simplifies the connections.

Should it be desired to use the composite set (or simplex set) on another line, two double cords terminating in double

plugs are used. Insert one end of one cord vertically in jacks *3* and *4* and the other end in the jacks corresponding to *1* and *2*, but on the line on which it is desired to use the set. Also, put one end of a second cord in jacks *7* and *8* and the other end of this cord in the jacks corresponding to *5* and *6*, but on the drop side of the particular line on which it is desired to put the set.

12. The Morse legs of the various sets are usually brought to jacks in the test panel, or if there is no room there, to an extra panel mounted for that purpose. The best arrangement is that shown in Fig. 7, which uses one jack *5* as the terminal of the line from the Morse board (the description of which will follow), jack *7* being arranged to act as a "looping-in" jack, by means of which a Morse set (relay and key) may be inserted in series with the Morse circuit in order to answer telegraph subscribers' calls or do any other business on the circuit.

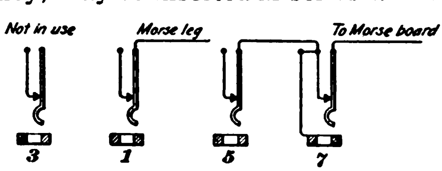


Fig. 7

Looping-in is accomplished by means of two cords terminating in a single plug with an extra sleeve insulated from the point. This sleeve makes contact with the sleeve of the jack, the normal contact and the sleeve of the jack being connected together as shown at jack *7*. The sleeves of the jacks, or *collars*, as they are frequently called, are usually dead, but they can be used if required. The Morse legs of the composite set are brought to jacks corresponding in position to jacks *1* and *2* in Fig. 6. Under normal conditions, a cord from jack *1* to jack *5*, Fig. 7, is necessary to keep the circuit closed. To move a telegraph subscriber from one Morse leg to another, pull out the cord from *1* to *5*, insert a plug attached to one end of a single patching cord in *5* and the plug attached to the other end in the Morse leg jack desired, corresponding in position to jack *1*.

13. Fig. 6 may also be used to show the arrangement of wiring the test board for a line leased by a subscriber for his

special use. In this case, a toll line *W* passes through jacks *1*, *2*–cross-connections *a c*, *b d*–jacks *3*, *4* to the toll-line drop *Y*. The subscriber loop *X* passes through jacks *5*, *6* –cross-connections *eg*, *f h*–jacks *7*, *8* to the subscriber's drop and answering jack across wires *Z*. By inserting a double, or twin, plug, such as is shown at *A* in Fig. 10, in jacks *1*, *5*, Fig. 6, and a similar plug in jacks *2*, *6*, the subscriber's loop *X* is connected directly to the toll line *W* and the other apparatus is cut off.

MORSE PANELS

14. A **Morse board** is simply a test panel or panels carrying horizontal rows of from four to six jacks, the connections of which are made entirely with a view of facilitating various Morse tests and connections. The Morse business necessitates the ability to connect a telegraph, or Morse, battery to any of the lines, or to remove it, as the case may be. From these considerations arise the necessity of a Morse board. A single row of jacks in a simple Morse-board panel

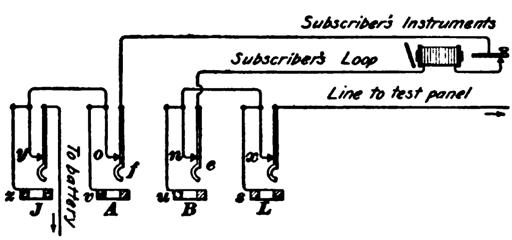


FIG. 8

is shown in Fig. 8. The line coming to the jack *L* is a cross-connection wire over to the test panel where it may be connected, as shown in Fig. 6, like the conductors *Y* to jacks *3*, *4*; or if the Morse wire is to be one side of a composite circuit, it will come to jack 7, Fig. 7, where marked to Morse board.

The contact of a jack that is permanently connected, or **strapped**, as it is termed, to the sleeve of the same jack is called simply the **normal** of the jack. Thus the contact *x*, Fig. 8, is the normal of jack *L*. Since the normal *x* is connected to the sleeve, this jack *L* may be used as a looping-in

jack by the Morse operator or monitor. From the normal x of jack L, the line goes to the normal n of jack B–spring e–one side of the subscriber's loop–his instruments, and back on the other side of the loop to spring f of jack A. The normal o of jack A is connected to the normal y of jack J and the line receives current through the spring of jack J which goes through a lamp of suitable resistance mounted in a bank of lamps and the battery to ground.

15. Test for Open Circuit.—To make a test for an open circuit, the Morse monitor cuts in his test set (key, relay, and sounder) by means of a two-contact plug inserted in jack L. A twin plug is then inserted in jacks A, B. This

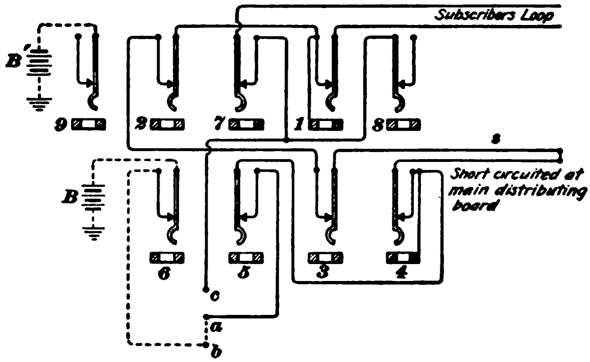


FIG. 9

connects e to f, and u to v; in other words, the subscriber's loop is short-circuited and a circuit is now closed from x through u–v to y. If this closes the circuit through the test set, the line is probably open in the telegraph subscriber's office. If this does not close the circuit through the test relay, a single plug connected through the test set to the side of the plug making contact with s, is inserted in a grounded jack, a number of which are provided for use in testing. If the test set now closes, the line is open toward the test panel. If this does not close the test circuit, the battery fuse is probably burned out or there is some trouble in the office wiring, to remedy which proper steps should be taken.

16. The wiring of a Morse board is shown in Fig. 9, where the subscriber loop coming in from the main distributing board is shown. One side of the loop passes through jack *1*–jack *2*–jack *3*, to the main distributing board, where it is short-circuited and returns through jack *4*–jack *5*–lug *a* –lug *b*–jack *6* to the Morse battery *B*, which usually consists of thirteen storage cells in series. The opposite side of the loop, after passing through jack *7*, ends at jack *8* and lug *c*. The remainder of the circuit is wired through the test board, as shown in Fig. 6. All jacks have collars, but they are used only where they are shown connected to the circuit.

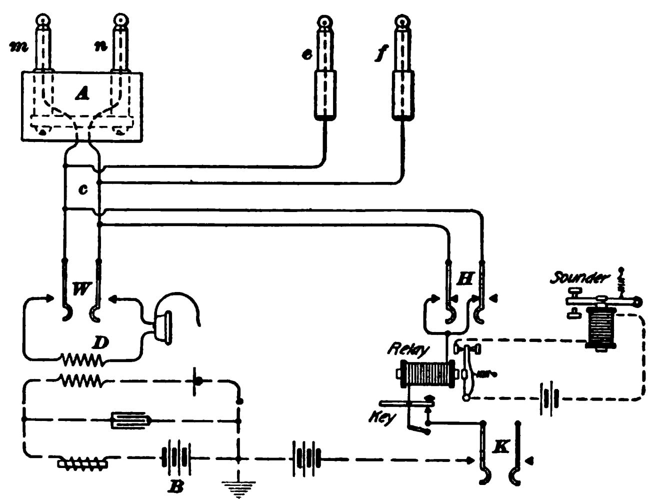


FIG. 10

The cord-circuit equipment consists of the regular testing circuit shown in Fig. 10, in which a twin plug *A* is wired to a listening key *W*, by means of which the telephone circuit *D* may be cut in. Bridged to each strand of the cord *c* is a single-strand cord attached to the single plugs *e*, *f*; they are used to test each side of the line independently of the other. The apparatus used for making these tests consists of an ordinary telegraph relay, key, and sounder. With the key *K* closed and *H* in normal position, the Morse set is connected to plugs *m*, *e*; with *H* also closed, the Morse set is connected

to plugs *n*, *f*. The other testing apparatus consists of a Wheatstone bridge wired to a plug, by means of which the regulation loop tests for grounds and crosses are made. No provision is made for testing switchboard trouble by means of a test circuit, similar to that used by the local companies, the Long-Distance Company not having adopted this class of test.

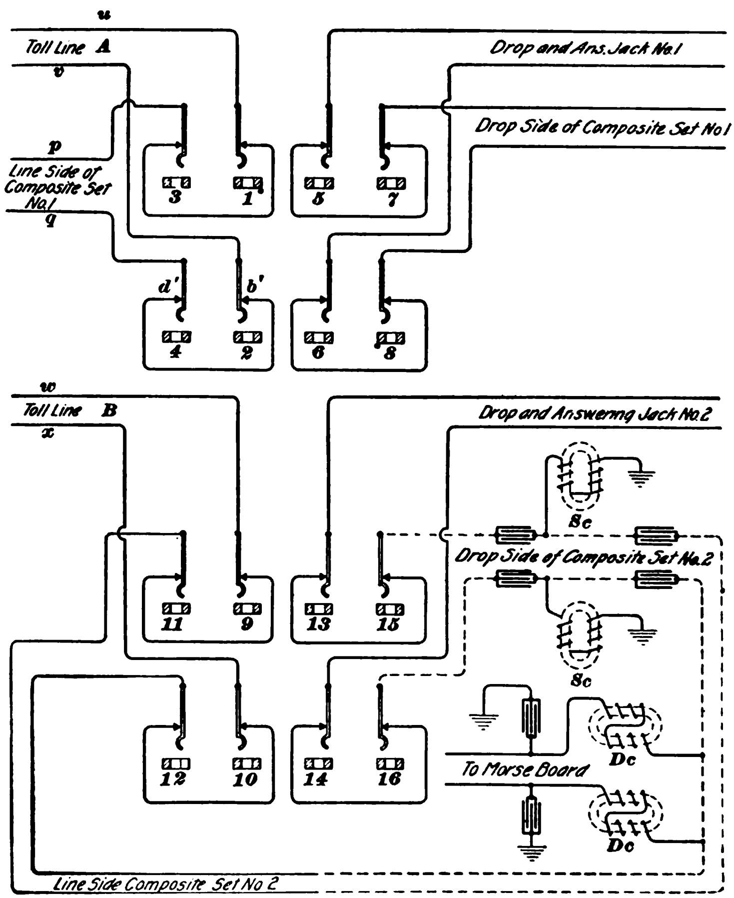


FIG. 11

17. Patching.—The test board is also used for testing, and making the proper connections between subscriber loops

and toll lines; and between toll lines, and also for what is called **patching.** This is resorted to when, as the result of a storm, only a few wires are in working condition, and circuits have to be made up of wires that are not mates. This is done by means of the plugs A, e, and f, Fig. 10. For example, suppose that in Fig. 11 conductors u, w, one on each of the toll lines A and B are defective and that it is desired to patch up a line by the use of conductors v, x, one on each of these lines. It will be necessary to connect the drop and composite set properly to conductors v, x. Let it be supposed that the drop and answering jack No. *1* usually connected to line A is to be retained. A single conductor cord has one plug inserted in jack *3* and the other plug is inserted in jack *10*. A circuit is thus made from the good conductor x through the patching cord to conductor p of the line side of the composite set No. *1*, which is usually connected to line A,–conductor q–d'–b'–good conductor v of line A.

The connecting-rack lugs, as shown at the bottom of Fig. 6, have been omitted in Fig. 11 for the sake of simplicity. There are extra batteries, like B', Fig. 9, of various potentials and polarities wired to the springs of some spare jacks so that with one plug of a single patching cord inserted in one of these jacks and the other plug in jack J, Fig. 8, and making contact with the sleeve, the line in Fig. 8 may be connected to any one of the extra batteries.

18. In Fig. 12 is shown a Morse and test board used at an intermediate station on the main line between New York and Chicago. On the key shelf are three complete Morse sets, each consisting of a relay R, key K, and sounder S. One set is permanently connected in a cord circuit while the other two sets may be connected to any circuit for testing purposes. On the rear of the shelf are a number of plugs used for various purposes and two twin plugs a, b associated with the receivers O, O' that are connected by flexible cords with the operator's plugs and jacks at j. The twin plugs may be used to listen or talk on any circuit in whose jacks they are inserted. A single transmitter hangs by flexible

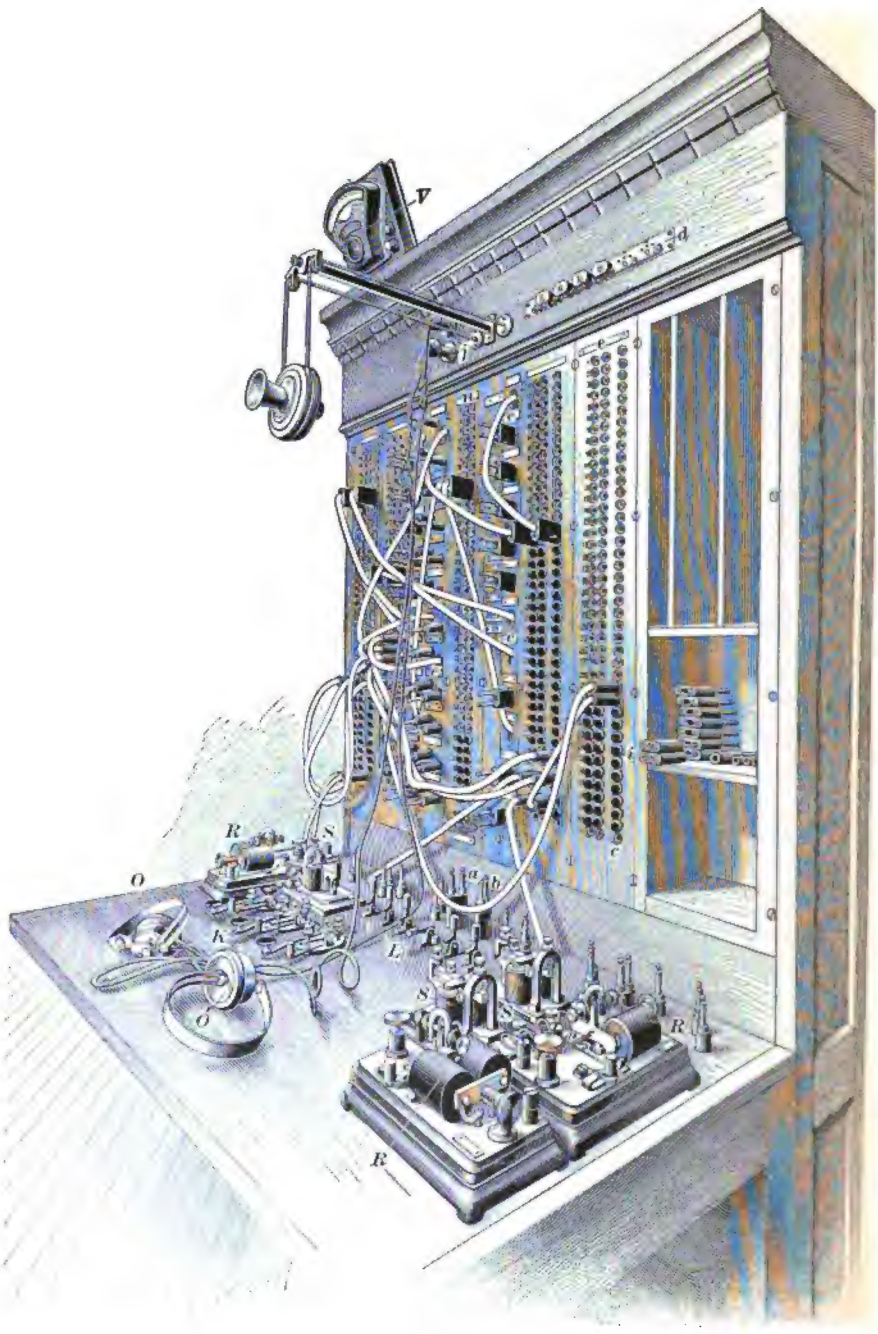


FIG. 12

cords from the top of the switchboard, while a voltmeter *V* is mounted on the top of the board where it can be read when the wire chief is standing in front of the board making tests. A row of keys used for various purposes in connection with the telephone head-set, is shown at *L*. One may be used to cut-in the battery, one, a listening key, connects the head-set across a pair of cords, and another cuts in the drop of a trunk to the toll switchboard.

The vertical rows of single jacks, such as *c*, are sometimes called transfer jacks; Morse batteries may be connected to some of these jacks. The voltmeter *V* may be connected to plugs for testing the battery or other circuits and a milliammeter is also usually provided and connects to plugs for measuring the current in the Morse circuits.

In case of trouble on a leased Morse loop, the telephone set may be used to communicate with the Morse subscriber through the same subscriber's regular exchange telephone. The jacks in the row *n* are connected to various local circuits.

19. The framework of a Morse and test board is about the height of that of a local switchboard. The jacks are mounted in rows on hard-rubber strips, which are, in turn, screwed to the wooden framework. There are quite a number of designation-card holders *e*, *e* that hold cards carrying the name of the subscriber loop or toll line, as the case may be. At the top are mounted a row *d* of drops to which are wired lines from the toll board used in calling the test board. Spare jacks associated with these drops are used in answering calls on these lines. The equipment of a separate Morse board differs from that of a test board only in the fact that the keyboard is equipped with telegraph apparatus for use in handling the Morse business. The section is also equipped with the regulation telephone circuit.

In Fig. 12 there are forty-one horizontal rows of jacks. When composite wiring is not used, each panel has a capacity of twenty rows east and twenty rows west, or twenty through circuits. When compositing is used, every other row of jacks is taken for the drop and line side of the

composite set, as shown in Fig. 6. The forty-first row of jacks is a spare row. The holes containing wooden plugs *i*, Fig. 12, are not now provided with jacks, but they can be when there are enough lines and business to require them. This particular board can be equipped with another complete panel when necessary.

TELEGRAPH APPARATUS

TELEGRAPH REPEATERS

20. A **telegraph repeater** consists of an arrangement of telegraph instruments whereby Morse signals coming over one line are automatically repeated or sent forwards on another line by a separate battery. As the length of a line increases, the ratio of conductor resistance to insulation resistance, increases until it becomes so large that satisfactory signals cannot be transmitted, no matter how much the battery power may be increased. Even if the insulation could be made sufficiently perfect, the line resistance would finally, as its length increased, become so high that it would require an electromotive force too high to be either safe, practical, or economical. An electromotive force above 300 volts requires very good insulation of the line wire and also tends to develop a ground or leak at a very weak point.

21. Furthermore, even if the resistance of a long line could be kept small and the insulation sufficiently high, and an electromotive force of sufficient strength could be used, the electrostatic capacity would be so high that it would seriously diminish the speed of signaling. On account of this retarding influence of the electrostatic capacity of the line and the inductance of the relays or other coils, both of which tend to delay the rise and fall of the current, the duration of contact at the distant relay is less than that at the sending key, thus causing a shortening of the signals and, hence, a reduction in the number of good signals that can be transmitted in one minute.

In such a case, the whole line, neglecting the leakage to earth at the insulators, has to be charged and discharged through the end offices. But if a long line is divided into sections, each section charges and discharges independently of the others, and the sections being shorter than the whole line, it is evident that they will all be charged and discharged quicker than if connected in one continuous line.

22. On a very long circuit with several repeaters, there would be a shortening of the signals at the far end due to the fact that, as each circuit is closed, a short delay occurs in the transmission of a signal because each armature has to move over a short distance from the rear to the front stop before the circuit is complete. This shortens the dots and dashes in proportion to the number of contacts to be closed, and thus the dots are sometimes wholly lost. For these reasons, it is necessary in operating a circuit containing one or more repeaters, to make the dots and the dashes firm and longer, or, as operators term it, the "sending should be heavy." The more repeaters there are in a circuit, the heavier should be the sending.

As a matter of fact and experience, the loss in speed due to the use of repeaters is not so great as is the gain in speed due to the quicker charging and discharging of the shorter sections into which the long line has been divided. Thus a long line can actually be worked faster and much more satisfactorily with repeaters than without, especially in wet weather when the leakage is large.

23. By the use of repeaters, it is possible to work long lines with wires of a reasonable size, fair insulation, and electromotive forces not unreasonably high, that could not be worked as one continuous line. In the United States, with large and comparatively low resistance wires, it is not usually customary to operate, directly, a circuit over 600 miles in length. However, on well-insulated lines of good conductivity, and especially through dry regions, circuits are sometimes worked much longer distances without repeaters.

24. An **automatic telegraph repeater** is one that will automatically repeat Morse signals in either direction. A telegraph operator is always necessary, however, to adjust and care for the telegraph instruments and batteries, but his time may be largely devoted to other duties. Telegraph repeaters, instruments, or circuits, will not be considered here from the point of view of a telegraph operator, but some of the repeaters used by telephone companies will be explained.

STANDARD REPEATER

25. Fig. 13 shows the theoretical connections of the the repeater used by the American Telephone and Telegraph Company and called their **standard repeater.** R, R' are ordinary 150-ohm or 250-ohm relays as desired. T, T' are especially made telegraph transmitters having additional

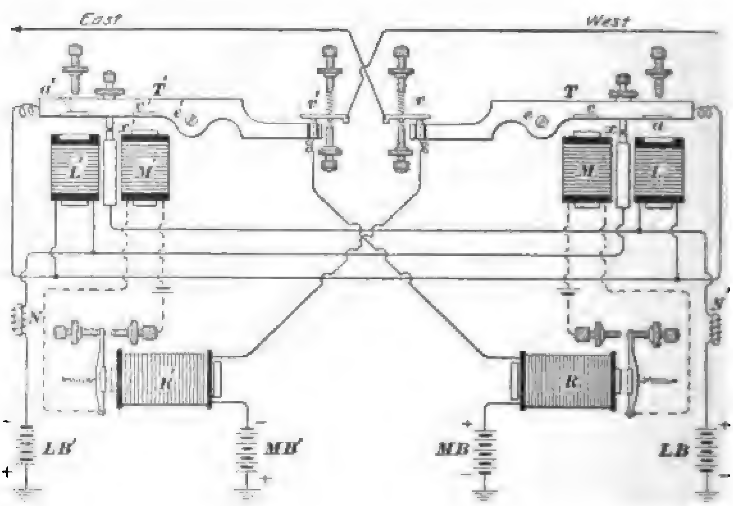


FIG. 13

20-ohm electromagnets L, L' under the extreme ends of the transmitter bars, to which are fastened the soft-iron armatures a, a', c, c'. The bars are pivoted at e, e' The magnets L, L' are fastened to the base by adjustable screws. which are used to draw them away from or advance them

closer to their armatures, as desired. Normally, all circuits are closed and the holding magnets L, L' have their coils short-circuited through the contacts x, x'. Current flows through the limiting resistances N, N' continuously, but only passes through the holding magnets when either the west or east line is open, which allows R or R' to open and deprives M' or M, respectively, of current. The dotted lines show the local circuits for operating the transmitters.

26. Operation.—When a telegraph operator at the distant western station opens his key and hence opens the west line, the relay R releases its armature, thus opening the local circuit through the magnet M of the transmitter T. The transmitter bar in its upward movement first opens the contact at x, which removes the shunt from around the holding magnet L', and allows it to receive current through $L\,B$–N'–x'–L'–N–$L\,B'$–ground and thus hold the bar of transmitter T' in the closed position. Passing upwards the bar of T next breaks the contact at v, thus opening the east line. Hence opening the west line at the western station opens the east line at the repeater, but the west line does not open at the repeater. Closing the western key will close R, M and the eastern circuit at v and the shunt around L' at x, thus restoring all circuits to their normal condition.

Should the east, desiring to stop and communicate with the sending operator at the western station while the eastern line is open at v, break, that is, open his key at the eastern station, the relay R' will remain open and just as soon as the bar of the transmitter T completes the next downward movement caused by the closing of the western key, the shunt at x around the magnet L' will be closed, thus allowing the bar of T' to fly up and open the west line at v'. The opening of the shunt at x' around the magnet L causes the magnet L to hold the lever T' down; thus, the eastern line is closed at v and the western line is open at v'. Hence, the eastern operator can now send to the western operator.

27. Adjustment of Standard Repeater.—In practice, the holding magnets L, L' should be just sufficiently near

their armatures to pull down the bar when the shunt is removed. If brought too close, the break is not sufficiently rapid. Getting one a little too far away will introduce a "rattle" in the repeater; or it may leave the line standing open when one side breaks.

The main-line contacts at *v*, *v'* should be as close as possible without arcing across. The springs on top of these little contact bars should be just strong enough to make good contact, but not too stiff.

To adjust the holding magnets, throw the two switches, usually provided on the repeater table, but not shown in this figure, to the left and open the two telegraph keys also provided but not shown here; taking firm hold of one transmitter bar, work it up and down slowly; the opposite transmitter bar should follow these motions. If it does not, adjust the holding magnet under it until it does so. Now change and operate the opposite bar by hand and adjust the holding magnet on the one first worked by hand. If this is done, the adjustment is sure to be correct. Only experienced men should attempt to adjust the magnet while the repeater is working.

ATHEARN REPEATER

28. In Fig. 14 is shown a general view of a repeater patented by W. E. Athearn, of New York. Several very decided improvements have been made, the aim being to simplify the apparatus and secure quicker and more direct action. Two ordinary 150-ohm relays are provided with the usual front stops *e*, *e'*, and back stops *f*, *f'*. In addition, each relay has two slender springs *a*, *b* separated by a hard-rubber washer *n*. These springs are fastened to the base and fit in between the two coils of the relay, although for the sake of clearness they are shown in this diagram as being in front of the coils. The armature lever *c* is very light and extends downwards from the pivot *d* to *o*, where it has a second armature facing the holding magnet *H* of 20 ohms resistance, which is fitted into a deep groove in the bottom of the base, which is a rather thick wooden one mounted on an iron

frame. Both relays, with their respective holding magnets, are mounted back to back on one long base.

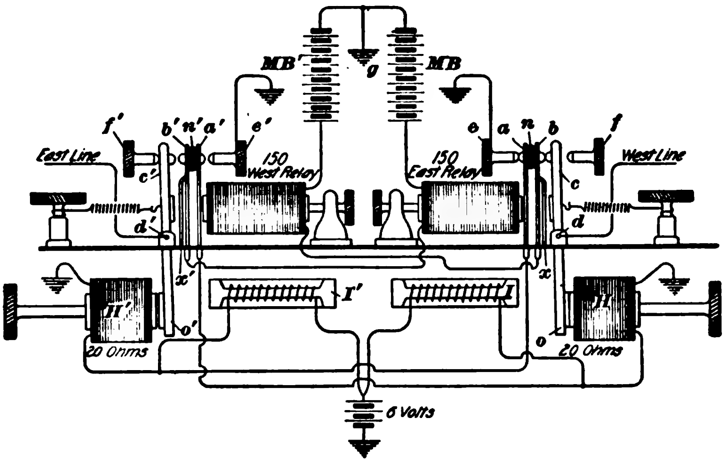


FIG. 14

29. Operation.—In the normal condition, all circuits are closed. If the western operator desires to send and opens his key, there is no current in the circuit: west line–c–b–west relay–MB'–g, and hence the west relay releases its armature. The first backward movement of this armature opens the circuit between e' and a'; this opens a shunt circuit to ground around the holding magnet H. This prevents the release of the armature o of the east relay when, a moment later, the balance of the backward movement of the armature c of the west relay opens the east line by breaking the contact between the spring b' and the armature lever c'. Thus, the eastern line is opened at c', but the *west line does not open* at the repeater. When the western operator closes his key, the west relay attracts its armature, closes the east line between b' and c', and then closes the shunt between e' and a' around the holding magnet H. All circuits are now restored to their normal condition.

Should the east, desiring to break, open his key while the eastern line is also open between c', b', the first complete forward motion of lever c' due to the closing of the western

key and west relay closes the circuit between a', e', and shunts the magnet H, which then releases the lever o, which, in its first backward movement, opens the circuit between a, e, thus removing the shunt from around the magnet H', which then holds the west relay lever closed. The eastern operator can then send to the western operator.

30. A novel feature of this repeater is the limiting resistances I, I', which, instead of being non-inductively wound, are wound on iron cores with heavy end lugs. It is stated that because of this inductance the magnets H, H' are rendered much quicker in action because, when the shunt is removed from one of these magnets, the inductance coil gives an instantaneous kick of much more than 6 volts, which helps to overcome the high impedance of the holding magnet for a rapidly increasing current and, therefore, to more rapidly build up its magnetism. From the lightness of the moving parts, this repeater should be very rapid and is apparently a long step in the right direction.

CONNECTING REPEATERS

31. Telegraph repeaters, when used on long composite circuits of the American Telephone and Telegraph Company, are connected up in two ways—either temporary or permanent. In large offices like New York and Chicago, they are permanently connected in the circuit; while at the intermediate points, as, for example, Dallastown, Pennsylvania, or Tadmore, Ohio, they are usually connected in the circuit temporarily. When connected permanently, the repeaters are wired back to the distributing board, where, by means of jumpers, connection is made with the Morse side of the composite sets. When connected temporarily, they are wired to cords and plugs, placed in a special panel on the Morse board. The Morse side of the composite sets are wired to a separate row of jacks, so that by merely inserting repeater plugs in these jacks, the proper connections can be made.

DUPLEX TELEGRAPH AND TELEPHONE SYSTEMS

32. In order to save the expense of construction and maintenance of more wires than are really necessary, it has been customary for a long time for telegraph companies to use one wire for the simultaneous transmission of several messages. The transmission of two telegraphic messages simultaneonsly in opposite directions over one line wire is called **duplex telegraphy.** On a duplex system, there is one sending and one receiving operator at each end of a circuit. The simultaneous transmission of four telegraph messages, two in each direction, over one line wire is called **quadruplex telegraphy.** On a quadruplex system, there are two sending and two receiving operators at each end of the line, or a total of eight operators. In telegraph systems, but one line wire, with the earth as a return, is required for a duplex or a quadruplex circuit.

DUPLEX TELEGRAPH AND COMPOSITE SYSTEM

33. One of the best arrangements for duplexing a composited wire is shown in Fig. 15, in which both sides of the composite set have been included in order to make the arrangement clearer. Line *2* may be duplexed in the same manner as line *1*. *R* is a polarized relay, that is, a relay that keeps its local circuit open when current flows through it in one certain direction, but closes this local circuit when current flows through it in the opposite direction. This relay is connected across the inductively wound coil *m*, *n*, which has a resistance of 1,000 ohms. It is inductively wound so as to force to ground, through the small condenser *A*, the sharp edges of the telegraph current, leaving a smoother current to pass through the portion of the circuit that is also used for telephoning. This is necessary to avoid the production of telegraph clicks or noises in the telephones. The condenser *A* also reduces the sparking at the contact points *h*, *i* of the telegraph pole changer *PC*.

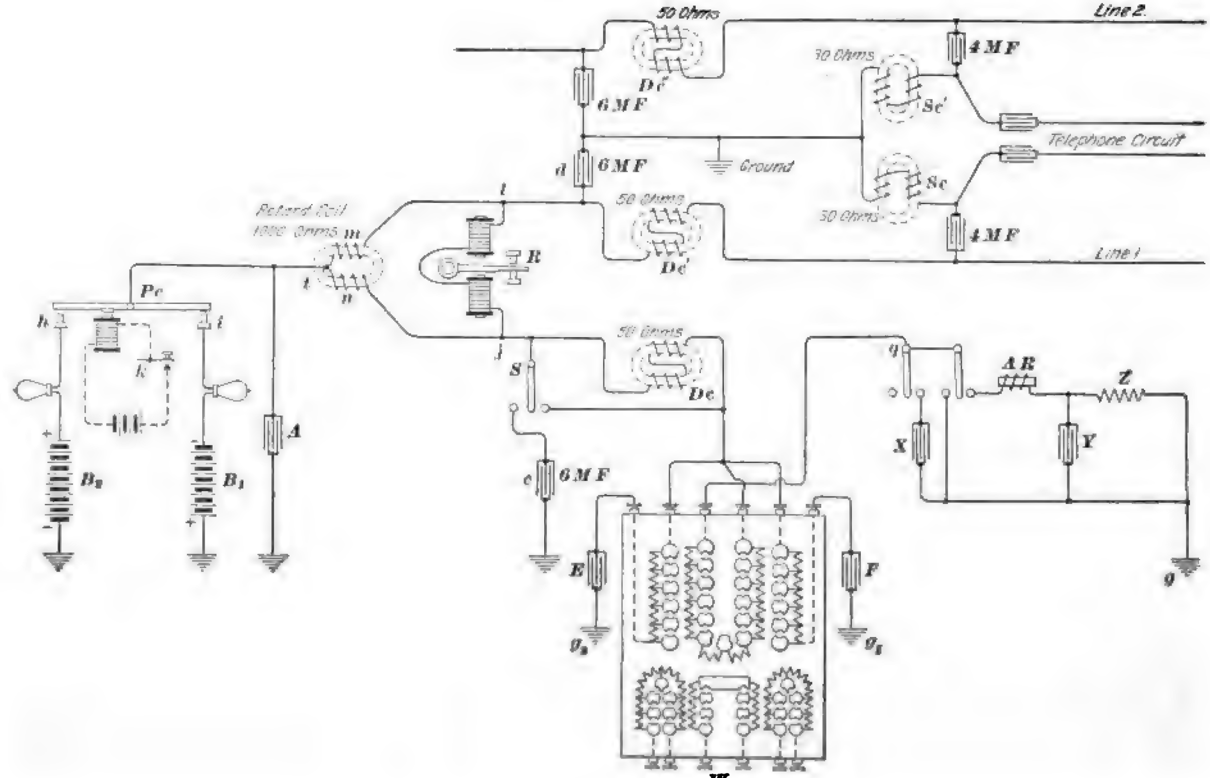

50 Ohms
Line 2.
4 M F
30 Ohms
Dc'
Sc'
6 M F
Telephone Circuit
d
6 M F
Ground
Sc
Retard Coil
1000 Ohms
m
t
n
l
50 Ohms
30 Ohms
4 M F
R
Dc
Line 1
Pc
h
i
k
j
S
50 Ohms
Dc
q
A R
Z
X
Y
A
B₂
B₁
c
6 M F
E
F
g₂
g₁
g
W

FIG. 15

34. Artificial Line.—The circuit from j through the various coils and condensers to the grounds g, g_1, g_2 constitutes what is called an **artificial line.** The more nearly the resistance, capacity, and inductance of this artificial line are equal to these same quantities in the real line and the more nearly they are arranged, or distributed, in the same manner, the better can the duplex telegraph set be balanced and the better will it work. The coil Dc is inserted to counteract the inductive kick from the corresponding coil Dc' in the real line, which occurs when the pole changer is being rapidly operated. The other resistances and condensers are adjusted to balance the line wire itself under various weather conditions. W is a form of resistance box regularly used by some telegraph companies; in this case, the lower resistances are not used.

35. The condenser c, when connected to the circuit by switch S, balances the discharge of the condenser d. The switch S may be used to cut out condenser c and short-circuit the coil Dc. Instead of connecting the wire q directly to ground, as is usually done in regular telegraph duplex systems, it is frequently necessary to balance the coils and condensers in the line circuit at the distant station, by the use of additional inductance at AR and capacity at X, Y. This is usually more necessary on short lines free of cable conductors, where the capacity of the line is insufficient to counteract the inductive kicks from the coils. If extra capacity is required and inserted at X, Y, it is necessary to connect a non-inductive resistance Z of from 100 to 500 ohms around Y.

36. Operation.—The sending telegraph operator uses the key k to send the message, thereby controlling the pole changer. The relay R controls a local circuit containing a battery and a sounder from which another operator reads the incoming message. The equipment at the distant station is exactly the same as shown in this figure.

With the transmitting keys k at each end open, the negative poles of similar voltage batteries B_1, B_2 are connected

to similar points t, t' at each end, as shown in Fig. 16 (a), and therefore the direction of the current in the various parts of the circuit are as shown in this figure. There is no current in the line wire l, l'. The relays R, R' are so polarized that they keep their local circuits open when currents

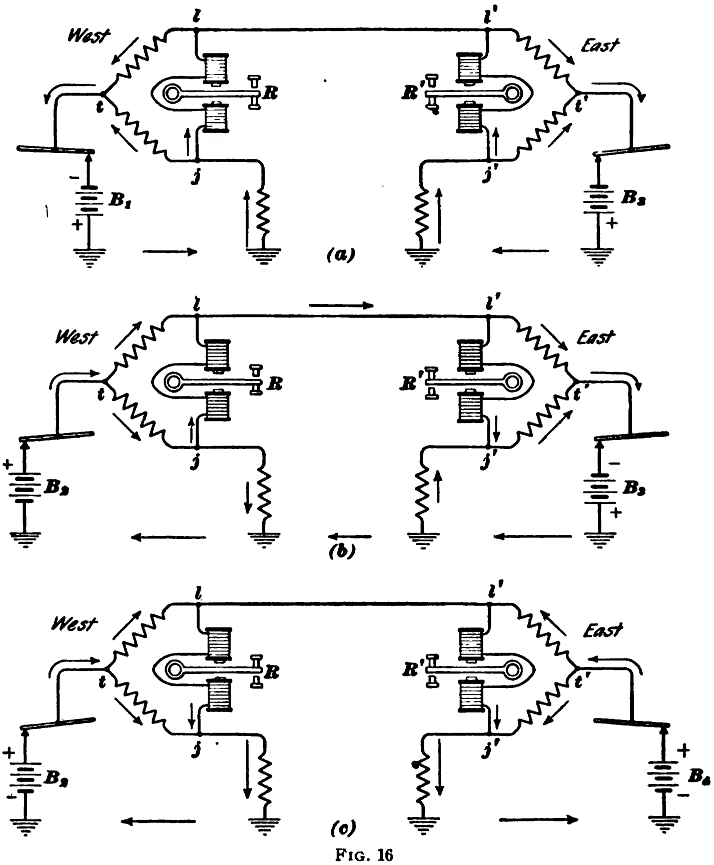


FIG. 16

flow through them from j to l, and from j' to l'. If the key k, Fig. 15, is closed, the battery B_2 will be substituted for B_1, the polarity at t will be reversed, and the direction of the current in the various parts of the circuit will be as shown in Fig. 16 (b). The current through R has not changed in

direction, hence it will not close its local circuit, but the direction of the current through R' has been reversed, hence it will close its local circuit. In a similar manner, it could be shown that, if the key at the western end were open and that at the eastern end closed, only the relay R would close its local circuit.

If both keys are closed, the positive poles of similar voltage batteries B_2, B_4 will be connected to points t, t', and the direction of the currents in the various parts of the circuit will be as shown in Fig. 16 (c). The currents through R, R' are in the opposite direction to that shown in Fig. 16 (a), and in the proper direction, therefore, to cause both relays to close their local circuits. Hence, it has been shown that the key at one end controls only the relay at the other end; consequently, messages may be sent simultaneously by the two sending operators at the two end stations and received by two other receiving operators at the same two end stations.

DUPLEX TELEGRAPH AND SIMPLEX SYSTEM

37. For use on simplexed circuits, it is not necessary to change the arrangement of the ordinary differential polar duplex telegraph system, but it improves the working of the duplex set to insert a simplex coil in the artificial line between the relay and the rheostat. The center connection of the simplex coil should form one of its terminals, while the two extreme, or free, ends of the simplex coil (those ordinarily connected to the lines) should be joined together to form the other terminal. Such a simplex circuit may be worked as a quadruplex almost as readily as it will work as a duplex, no additional apparatus being necessary, but an extra careful balance is required.

DIFFICULTIES ON DUPLEX TELEGRAPH AND TELEPHONE SYSTEMS

38. At first glance, it would seem a simple matter to duplex one side of a composited circuit; but in practice, a very disagreeable kick is experienced for which, except in

some cases, there seems to be no remedy to the inexperienced. It has been found that if the artificial line is made as nearly as possible like the main line, both as regards capacity and inductance, as well as resistance, this kick almost entirely disappears. Another feature that at first causes considerable trouble is a sharp click produced by the Morse current in the telephone receiver. To remove this, insert a retardation coil in the line circuit between the pole changer and the point *t*, Fig. 15. The amount of this inductive resistance necessary will vary according to the length of circuit and the amount of battery used, but a few experiments readily determines the amount required. Too much inductive resistance will reduce the margin, that is, the change in the strength of the telegraph current through the relays, too much; and if enough is inserted to reduce the noise in the telephone to a point where conversation is not seriously affected, this is about the best that can be attained.

On some circuits in Texas, it was found that by inserting one-half of a spare composite set next to the relay in the artificial line of a composite system, duplexing was possible over lines previously entirely impossible.

The general service on any duplex worked on a composite or simplexed circuit is, of course, hardly equal to that on a straight wire, that is, on a line used only for telegraph purposes, because in bad weather the margin decreases very rapidly. However, a short telephone circuit may be worked on a wire used duplex without serious detriment to the Morse. Intermediate telegraph stations cannot be inserted in a duplex telegraph circuit.

EFFECTS OF COMPOSITING OR SIMPLEXING CIRCUITS

39. The introduction of retardation coils and condensers is of but little, if any, detriment to telephonic transmission, but the Morse circuits suffer considerably. An operator accustomed to working a straight Morse wire, if changed to a side of a composite, will at once complain of the wire being sticky and slow. The margin or range of adjustment

becomes much smaller and it is necessary to "pull up" much higher, that is, move the relay cores back or increase the tension of the retractile spring, or both, in order to receive the Morse signals from the distant office; but although the circuit seems very slow it will readily transmit messages sent at ordinary speed. Sometimes several of these composited circuits are connected together through repeaters for a long line, in which case the wire will be slow and hard to keep in good working order or, as it is termed by telegraph operators, "lined up"; the margin, or variation in current strength, will be so small that repeater stations will have difficulty in adjusting.

Sometimes a long cable loop between the exchange and a telegraph subscriber's office forms part of a composite wire. In this case, the subscriber will usually complain of poor service. The capacity of the long loop added to the capacity of the open wire and the composite sets makes an impedance equal to a very long line. In wet weather, the lack of margin becomes very noticeable.

40. Simplex circuits act much the same as composited ones, but the slowness may be taken as due more to inductance than to capacity. In heavy, that is, damp, weather, these circuits become very heavy (hard to work) owing to the fact that there are two wires to pick up leaks instead of one, while the extra conductivity of the lines is usually more than compensated for by the addition of the coils of the simplex set.

41. F. F. Fowle states that one terminal set of standard Bell composite apparatus impairs transmission to the same extent as the introduction of approximately 1.25 miles of No. 19 B. & S. cable conductors, or 35.6 miles of bare overhead No. 8 B. W. G. copper wire. The effect of two terminal sets will be equal to 71.2 miles of No. 8 B. W. G. Therefore, it is economy to composite only long trunk lines without intermediate telephone or telegraph stations.

The simplex system is somewhat more flexible, but does not present the same economy of line as the composite.

The repeating-coil method, which is not as efficient as the impedance-coil method, is employed when grounded ringing generators must be connected to the line, which would otherwise ground the telegraph circuit and cause the relays to chatter. The effect of a repeating coil of the most efficient type introduced into the line at the terminal is equivalent to the introduction of 1 mile of No. 19 B. & S. gauge cable conductor, or 28.5 miles of bare overhead No. 8 B. W. G. copper wire.

The effect of an impedance-coil simplex set may be considered as equivalent to $\frac{1}{4}$ mile of cable. It will be economical to simplex a bare overhead line, consisting of copper wire weighing 595 pounds per mile, provided that the number of simplexed connections does not exceed twenty. Intermediate telephone stations bridged on the line require no simplex apparatus, and this feature adapts the simplex system to short lines having intermediate telephone stations. An intermediate telegraph station at which there is no telephone may be equipped with a repeating coil, if the station is not near either terminal, because the introduction of an efficient coil has less effect if the coil is in the center of the line. The simplex system adapts itself to a greater range of traffic conditions than the composite, but it is especially adaptable to circuits having intermediate stations, either telephone or telegraph. The Morse side of the composite system may be worked either single or duplex, and on the simplex system the Morse circuit may be worked single, duplex, or quadruplex.

STORAGE BATTERIES

GENERAL DESCRIPTION

1. A **storage battery, secondary battery,** or **accumulator,** as it is variously called, is an apparatus consisting of certain materials so arranged that when they have undergone chemical action, due to the influence of a current of electricity, the combination has acquired the properties of a primary cell and is enabled to discharge into a closed circuit approximately the same quantity of electricity as the original charge. Strictly speaking, a storage battery is a group of individual cells connected together, but the term battery is often used when a single cell is meant.

Many forms of primary cell may, when exhausted, be more or less regenerated by passing through them, in the opposite direction to the current they produce, a current from some external source. It is customary, however, to consider as accumulators only those cells whose original construction is similar to an exhausted battery; that is, they cannot be used as sources of electricity until they have been charged by passing a current through them.

Much confusion exists in the use of the terms positive and negative when speaking of the plates of a secondary cell, for in charging the cell the current is in the reverse direction to that which flows when the cell is acting as a primary cell and discharging; it is customary, however, to speak of the plate at which the current enters the cell (while charging) as the *positive plate.* In fact, whether charging or discharging, this plate is at a higher potential than the other, which justifies this use of the term, although with respect to the chemical

actions in the cell the positive and the negative plates are reversed in the two operations.

Accumulators may be divided into two general classes: (1) *lead accumulators*, and (2) *bimetallic accumulators;* the cells now in use are almost wholly of the first class.

LEAD ACCUMULATORS

PLANTÉ CELL

2. The original **lead accumulator,** as made by Planté, consists of two plates of lead, usually rolled together in a spiral and separated by strips of rubber or other suitable insulating material, placed in dilute sulphuric acid. On sending a current from some external source through this cell, the water becomes decomposed—the oxygen combines with the positive plate, forming lead oxide or peroxide, while the hydrogen collects at the negative plate.

On disconnecting the source of the applied current, and completing the external circuit of the cell, the water is again decomposed—the oxygen uniting with the hydrogen collected at the negative plate and with the lead plate itself, and the hydrogen uniting with the oxygen of the oxide of lead at the positive plate—thus producing a current in the opposite direction to the applied current.

Owing to the fact that the formation of the layer of oxide prevents further oxidation, the amount of chemical change due to the applied current is small, so the secondary current from the cell is of short duration; after this current has ceased, however, the surface of the positive plate is much increased, owing to the removal of the oxygen from the lead oxide, leaving the metallic lead in a spongy form. On again sending a current through the cell a further oxidation of this (positive) plate takes place, and by continuing this process, reversing the current each time it is sent through, both positive and negative plates become porous to a considerable depth, thus very much increasing the surface on

which the oxidation can take place. This process might be carried on until the whole plate is reduced to spongy lead; in that case the plate would not hold together, so a sufficient amount of the original plate must be left for mechanical strength. After the plates are so *formed*, they are ready to be used as an accumulator.

This forming process is, however, too slow and expensive for commercial use. Batteries in which the Planté type of plate is used are now formed by special electrochemical methods, so that the active material can be produced in a comparatively short time.

FAURE CELL

3. Another method of preparing the plates is to apply the active substance in the form of a paste. This process was invented by Faure. The first charging current converts the paste on the positive plate into lead peroxide, and that on the negative into spongy lead. The substance applied may be lead oxide (litharge) PbO, lead sulphate, minium Pb_3O_4, lead peroxide PbO_2, or mixtures of these substances.

The substances are applied in various ways; one method is to make a paste of Pb_3O_4 (minium) with dilute sulphuric acid for the positive and a similar paste with PbO (litharge) for the negative. The sulphuric acid and the litharge combine to form lead sulphate and water. On the positive plate the acid combines with Pb_3O_4 to form lead peroxide, lead sulphate, and water. In each case the action is only partial, the amount of lead sulphate and lead peroxide formed depending on the strength of the acid solution. These pastes were originally applied directly to the surface of the plain lead plate, but as they proved to be only slightly adhesive, the plates were prepared by scratching or otherwise roughening the surface, which process has been gradually extended until the lead plates are now cast into grids, or latticework plates, in the spaces of which the paste is applied.

The grids are usually designed to hold the active material securely in position; to this end their perforations are not of the same area throughout the thickness of the plate, but

wider or narrower in the center, so as to hold the filling of active material by the dovetailing action of their shape.

After the grids have been filled with active material, they are set up in pairs in suitable vessels and surrounded by an electrolyte consisting of sulphuric acid diluted to about 1.17 specific gravity, which density corresponds to about 23 per cent. of acid in the liquid. A charging current is then sent through the cell from some external source; the action of this current decomposes the water, the oxygen of which further oxidizes the lead oxide (litharge or minium) to peroxide, at the positive plate, the hydrogen going to the negative plate, where it reduces the lead sulphate to spongy lead by uniting with SO_4, forming sulphuric acid. Thus, the active material becomes lead peroxide on the positive plate and spongy lead on the negative. By many investigators this lead peroxide is thought to be hydrated lead peroxide; that is, it contains a certain amount of hydrogen and oxygen in excess of the normal peroxide, and is represented by the formula $H_2Pb_2O_6$. This, as well as many of the actions that occur in accumulators, is not clearly established as yet.

Continuing the charging current when all the active material is thus converted produces no effect, except to further decompose the water; the resulting gases pass off through the water, giving it a milky appearance. This phenomenon is known as *gassing*, or boiling, and is an indication that the cells are fully charged.

4. On discontinuing the charging current at the gassing point and completing the external circuit of the cell, a current will flow in the opposite direction to that of the charging current, the resulting chemical action being to change lead peroxide to lead sulphate at the positive plate and the spongy lead to lead sulphate at the negative. The sulphates thus formed may not be all of the same proportions; one may exist as red, another as yellow, and a third as white crystals, of which the white sulphate is best known, as it is formed when the cell is considerably discharged, and is extremely troublesome. This discharge may be continued until all

chemical action ceases and the E. M. F. consequently falls to zero; but this is not advisable, since, if the discharge is carried beyond a certain point, the red or yellow sulphates, probably by combination with the litharge, PbO, form the white insoluble sulphate; this, being a non-conductor, materially increases the internal resistance of the cell, and when removed usually carries some of the active material with it, as it is very adhesive.

The exact nature of the chemical reactions taking place in a storage cell are not altogether understood. There are a number of more or less complicated secondary reactions, but it is now generally accepted that the main reaction on charging is the formation of lead peroxide at the positive plate and spongy lead at the negative; on discharging, the final result is the formation of lead sulphate on both plates, as explained above. The reaction may be expressed as follows:

discharging →

charged condition *discharged condition*

+plate electrolyte −plate +plate −plate

$$PbO_2 + 2H_2SO_4 + Pb = PbSO_4 + 2H_2O + PbSO_4 + \text{electrical energy}$$

← charging

The left-hand side of the equation represents the fully charged condition. The active material on the positive plate is lead peroxide and that on the negative, spongy lead. These plates are immersed in the electrolyte containing sulphuric acid, H_2SO_4. When the cell is discharged, it gives up electrical energy and the substances are changed to those shown on the right-hand side of the equation. Lead sulphate, $PbSO_4$, is formed on both plates and water is also formed. This water mixes with the electrolyte and lowers its specific gravity. When the operation is reversed and the cells charged, the plates are in the initial condition represented by the right-hand side of the equation. Electrical energy is supplied from an outside source and the lead sulphate on the positive plate is converted into lead peroxide, while that on the negative is changed into spongy lead. Sulphuric acid is also formed and this mixes with the electrolyte, causing the specific gravity to increase as the charging progresses. When the cells have

been properly charged, the positive plate is a chocolate color, while the negative is a slaty gray.

The presence of the insoluble sulphate is made apparent by the formation of a white coating or glaze over the plates, which are then said to be *sulphated.* If the cells are discharged and left to stand with the electrolyte in place, sulphating takes place rapidly.

5. It has been shown that sulphuric acid is formed during the charge and decomposed during discharge; thus, the proportions of it in the electrolyte, consequently, the density of the electrolyte, vary with the state of charge of the cell; starting with a specific gravity of 1.150, the specific gravity will be found to be about 1.20 when the cell is fully charged, indicating the presence of about 27 per cent. of sulphuric acid in the electrolyte. The variation in density of the electrolyte with discharge and charge is shown by the lower curves in Figs. 1 and 2.

The E. M. F. of this cell is approximately 2 volts, being 2.04 when the discharge starts, which gradually falls to 1.75 volts when nearly discharged; beyond this point, further discharging causes the E. M. F. to fall more rapidly, the decrease after 1.75 volts being very marked. The upper curves in Figs. 1 and 2 show the variation in the potential difference at the terminals of a cell, the curve in Fig. 1 showing the falling off during discharge and Fig. 2 the rise during charge.

6. Buckling.—The rating of accumulators is usually based on their capacity when discharged to an E. M. F. of 1.75 or 1.8 volts; cells should not be continuously discharged to below 1.75 volts, as below this point injurious sulphating will occur. This sulphating may lead to a distortion of the positive plate, known as **buckling**, unless the grids are strong mechanically. As the plates are located very close together in the cells to reduce the internal resistance, buckling is liable to cause the plates to touch, thus short-circuiting the cell.

The cause of buckling seems to be the formation of sulphate

in the plugs of active material that fill the spaces of the grids, thus causing an expansion; lead having very little elasticity, the grid is forced out of shape. As frequently constructed, the edges of the grid are heavier than the intermediate portion, so that the effect of the distortion is to bulge the plate in the center. If the plates are not discharged too far and too rapidly, the expansion of the active material is gradual, causing the grid to stretch evenly.

7. Rating of Cells.—The quantity of electricity that may be taken from a completely charged cell depends on the amount (weight) of material altered by the chemical action, as in a primary cell; while the rate at which this material is altered, consequently, the rate at which the electricity can be taken out (the rate of discharge in amperes), and, to a large extent, the amount of material altered, depends on the surface of the active material exposed to the chemical action.

Cells are rated at a certain number of ampere-hours capacity, depending on both the weight and the surface area of the active material in the cell; a certain economical discharge rate is also recommended, depending on the surface of the plates exposed to the electrolyte. If this discharge rate be continually exceeded, the chemical action goes on too rapidly, the white sulphate is formed in the active material of the positive plate, finally causing disintegration of the active material, even if the discharge is not carried beyond the point (1.75) given above. With the ordinary construction, the normal discharge rate is about .04 ampere per square inch of surface (both sides) of positive plate, and the discharge capacity about 4 ampere-hours per pound of plate (both positive and negative plate included).

8. Change of E. M. F. With Discharge.—The upper curve in Fig. 1 shows the manner in which the E. M. F. of an accumulator falls as the discharge proceeds. In this case the cell was connected to a variable external resistance, such that about the normal discharge current, as advised by the manufacturers, was maintained throughout the test in the external

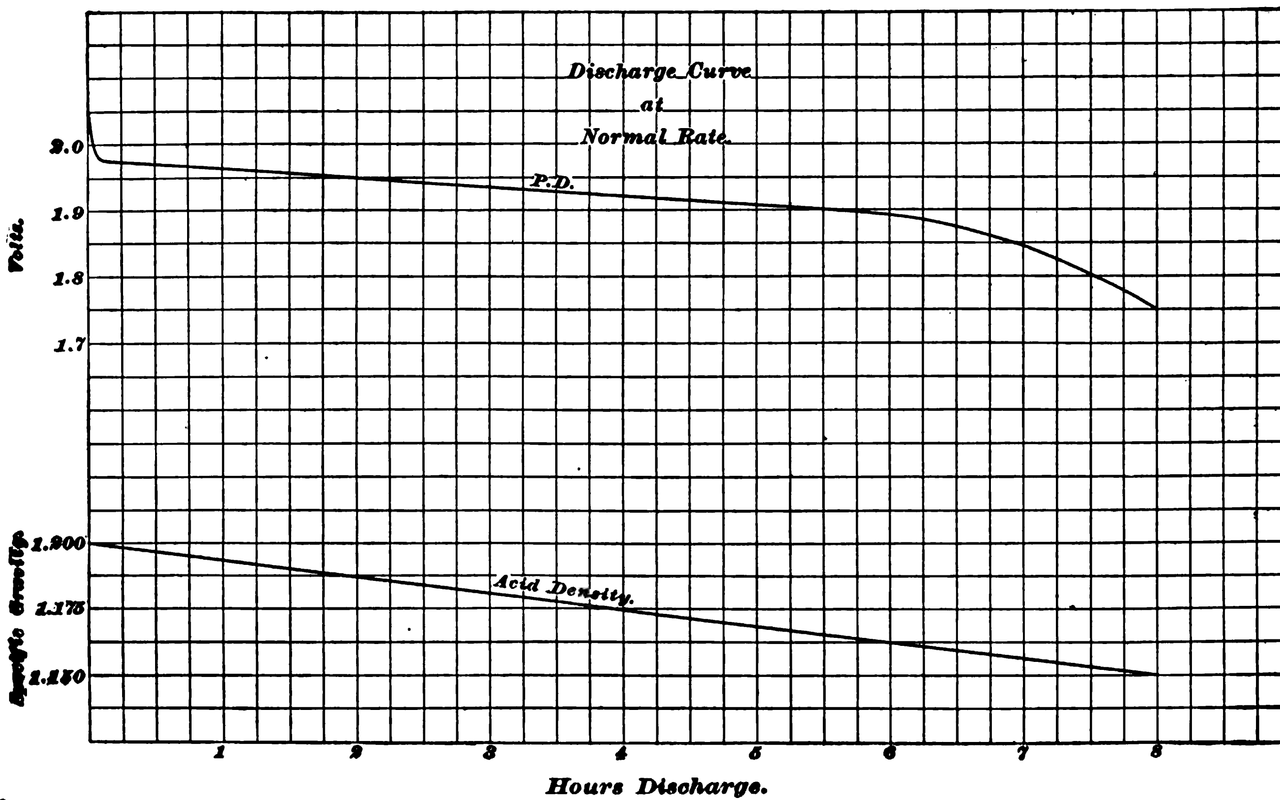

Discharge Curve
at
Normal Rate.
P.D.
Acid Density.
Volts.
2.0
1.9
1.8
1.7
Specific Gravity.
1.200
1.175
1.150
1
2
3
4
5
6
7
8
Hours Discharge.

FIG. 1

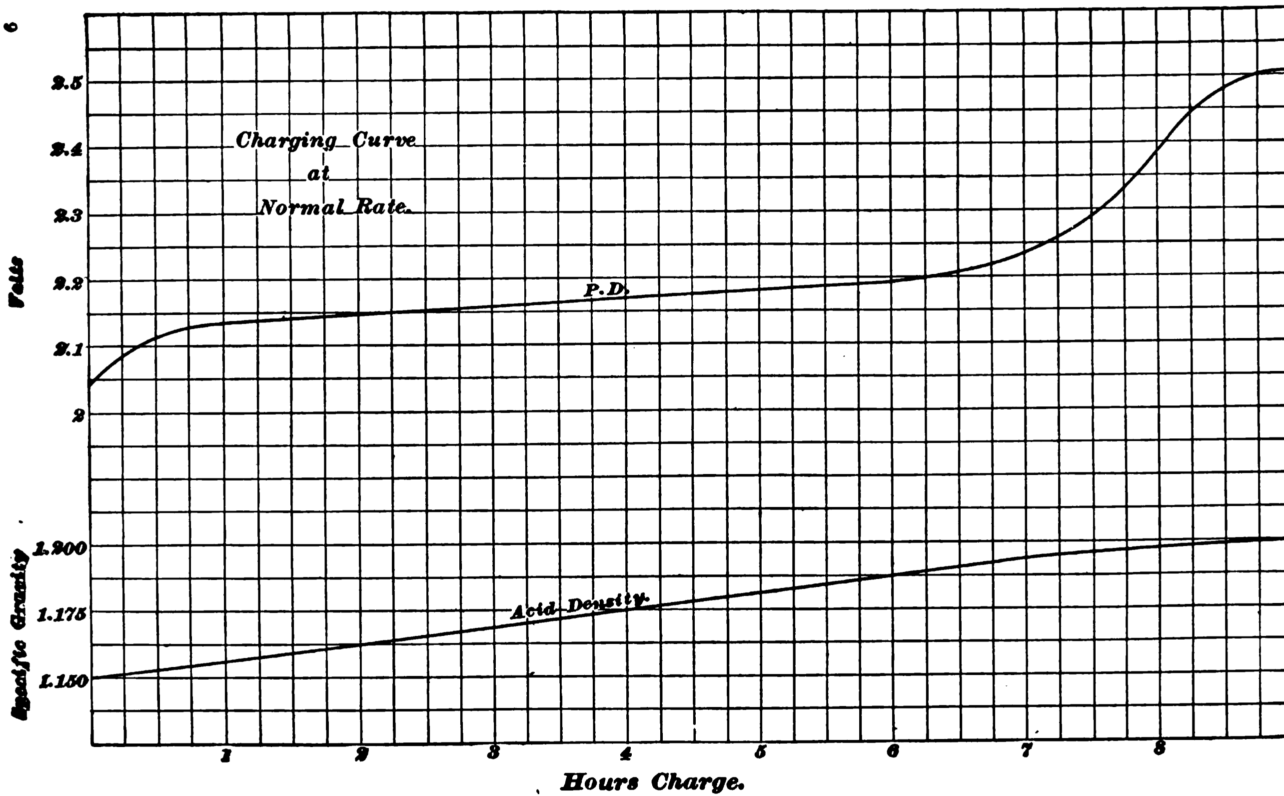

Charging Curve
at
Normal Rate.
P.D.
Acid Density.
Volts
2.5
2.4
2.3
2.2
2.1
2
Specific Gravity
1.200
1.175
1.150
1
2
3
4
5
6
7
8
9
Hours Charge.

FIG. 2

circuit. The state of polarization of the slight surface layer of both plates resulting from the charge causes the E. M. F. to be high at first, but as this is quickly disposed of, the E. M. F. falls in the first 5 minutes or so to 1.98 volts; on continuing the discharge, the E. M. F. falls slowly and evenly until after 8 hours of discharging the E. M. F. falls to 1.75 volts. If the discharge is continued beyond this point, the nature of the chemical action changes somewhat, and the fall of E. M. F. becomes more rapid.

This falling off of the E. M. F. is due to the weakening of the acid solution and to the gradual changing of the spongy lead on the one plate and the peroxide on the other to sulphate. As this reduction can only go on at the points where the acid is in contact with the spongy lead or the peroxide, it is evident that the interior portions of the active material are affected much more slowly than the surface, as the acid penetrates the active material only at a comparatively slow rate. On this account, discharging at slow rates allows the active material to be more uniformly and thoroughly acted on, thus giving a greater output.

This also accounts for the fact that on discontinuing the discharge at any point the E. M. F. will soon rise to practically its original value, 2.04 volts; for unless the cell is entirely discharged there is always some unconverted active material in the interior of the plate, which serves to give the original E. M. F. when reached by the acid. If the discharge is resumed, this acid is soon exhausted, and the E. M. F. rapidly falls to the value it had when the discharge was stopped.

In the above case, the product of the amperes and the hours will give the output of the accumulator in ampere-hours; if the discharge rate had been greater, the output in ampere-hours would have been diminished, the discharge being continued until the E. M. F. falls to the same value in each case. Conversely, if the discharge rate had been lower, the output would have been increased.

For example, assume the limiting E. M. F. to be 1.75 volts. In a certain cell, with a discharge current of 30 amperes, the E. M. F. reaches its limit in 8 hours, giving an output of

240 ampere-hours. If the discharge current were 40 amperes, the limiting E. M. F. would be reached in about 5 hours, giving an output of only 200 ampere-hours, while if it were 20 amperes, the limiting E. M. F. would not be reached for about 13 hours, giving an output of 260 ampere-hours.

For the sake of uniformity, the rating of the capacity of accumulators is made on the basis of a discharge current that will cause the E. M. F. to fall to 1.75 volts in 8 hours, although most manufacturers give tables showing the comparative capacity of the various sizes of cells at other rates of discharge. The rate of charge (charging current) for accumulators of this class should be about the same as the normal (8-hour) discharge rate, although much smaller currents, continued for a proportionately longer time, may be used.

EFFICIENCY OF STORAGE CELLS

9. Although storage batteries do not store electricity, they certainly do store energy by converting the kinetic energy of the electric current into chemical potential energy, which may be realized as kinetic energy again. The efficiency of the accumulator (or of any other means of storing or transforming energy) is the output divided by the input. This quotient is always less than 1, as the accumulator is not a perfect storer of energy; that is, there are certain losses in the transformation of kinetic electrical to potential chemical energy, and vice versa, besides the loss of the energy required to force the current through the cell, that is, the loss due to the resistance of the plates and electrolyte.

10. Ampere-Hour Efficiency.—The input and output of an accumulator may be expressed either in ampere-hours (the quantity of electricity) or in watt-hours (the work done by the current). If secondary cells of this class be fully charged at normal rate, after a discharge to 1.75 volts, and then discharged to the same point, also at normal rate, the **ampere-hour efficiency** will be ordinarily from .87 to .93, or 87 to 93 per cent. If charged and discharged to the same point at very slow rates, this efficiency may rise to 96 or 97 per cent.

11. Watt-Hour Efficiency.—The **watt-hour efficiency** at normal rates of charge and discharge is lower, being from 70 to 80 per cent., depending on the construction of the cell. When batteries are used for regulating purposes to take up rapid load fluctuations, the battery is alternately charged and discharged and the chemical action is confined largely to a thin surface film on the plates. Under such circumstances the watt-hour efficiency becomes considerably higher than when the battery charges and discharges continuously, and the watt-hour efficiency may be as high as from 92 to 94 per cent.

The cause of the loss represented by the foregoing figures is, for the ampere-hour efficiency, due to the fact that the charging current must perform several chemical decompositions, the elements of which either do not recombine or, recombining, do not give up their potential energy in the form of electrical energy.

The loss shown in the watt-hour efficiency figures is due partly to the fact that the E. M. F. of charge is higher than that of discharge, partly to the E. M. F. required to perform the wasteful chemical actions referred to above, and partly to the drop in volts caused by the passage of the current against the resistance of the plates and electrolyte. This drop adds to the E. M. F. required to perform the chemical decompositions in charging, and subtracts from the E. M. F. due to the chemical recompositions, and its amount depends more on the construction of the cell than does the loss represented by the ampere-hour efficiency, as it varies with the shape and size of the plates, their distance apart, their state of charge (on account of variations of the resistance of the electrolyte as the percentage of acid varies), the rate of charge and discharge, and other conditions.

The loss due to the internal resistance in well-designed cells usually amounts to about 3 per cent. at normal rates of charge and discharge; the loss is correspondingly less at low rates and more at high rates, being proportional to the square of the current flowing.

These efficiency figures, as stated, are given for a discharge

to 1.75 volts E. M. F., the usual manufacturers' rating; if the cells are not discharged to so great an extent, both ampere-hour and watt-hour efficiencies are higher.

12. Resistance of Cells.—In a good modern cell exposing about 1,100 square inches of positive-plate surface, and listed as having 400 ampere-hours capacity, the internal ohmic resistance is about .0007 ohm when charged. Cells of greater capacity have a proportionately lower resistance.

CHARGING E. M. F.

13. The E. M. F. required to send a given charging current through a secondary cell varies with the state of charge of the cell. Fig. 2 shows the E. M. F. required to charge the same type of cell that gave the discharge E. M. F. curve, Fig. 1. The curve shows the voltage across the terminals of the cell when it is being charged at the normal rate.

This curve shows that the charging E. M. F. during the first hour rises at a comparatively rapid rate from 2.04 to 2.13 volts. During the next 5 hours the rise in voltage is slower and practically uniform, having become 2.19 volts at the end of 6 hours. For the next 2½ hours the rise in voltage becomes more rapid and at the end of 8 hours reaches 2.38 volts, and at 8½ hours 2.48 volts. On continuing the charging current beyond the 8½-hour period the E. M. F. rises a little more, and then remains practically constant at about 2.50 volts; as the only action that now takes place is the decomposition of the electrolyte, giving off gas, further charging will only result in a waste of energy.

From this curve it appears that the cell became completely charged in practically 9 hours; as the discharge curve, Fig. 1, shows that with the same number of amperes the discharge is complete (to 1.75 volts) in 8 hours, the ampere-hour efficiency of this cell is $\frac{8}{9}$, or nearly 90 per cent.

CONSTRUCTION OF LEAD-SULPHURIC ACID CELLS

14. The usual construction of **lead-sulphuric acid cells** is as follows: The plates and electrolyte are contained in a vessel of approximately cubical form; this vessel is of

glass, if the cells are not intended to be portable, the glass allowing the examination of the condition of the plates while the cell is in operation. If the cells are intended to be portable, the vessel is usually made of hard rubber, or of wood lined with rubber or lead. Very large accumulators for central-station use are set up in lead-lined wooden tanks.

The plates are usually approximately square, except in large cells, and from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch thick, according to size. To get a large surface area without using single large plates, and to allow of one size of plate being used for cells of various capacities, each cell contains a number of positive and negative plates arranged alternately side by side a short distance apart. The number of negative plates is always one more than the number of positive plates, so that each side of each positive plate has presented to it the surface of a negative. All like plates are connected together by a connecting strap, usually at one corner of the plate. The arrangement of a widely used type of cell that will be described more in detail later is represented in Fig. 3, where *a*, *a* are the positive plates and *b*, *b* the negative. From a corner of each plate a lug projects; those on the negative plates are joined to a connecting strap, and those on the positive plates to another; the projections on the plates rest on the edges of the jar so that the bottoms of the plates are some distance from the bottom of the jar. This is done in order to prevent any active material or foreign matter that may accumulate in the bottom of the cell, from short-circuiting

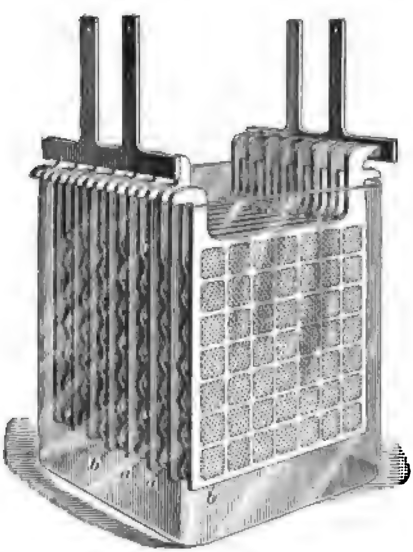


FIG. 3

the plates. The joints are made by a process called *burning*, which consists in melting the lugs and straps together by a hydrogen flame; this flame absorbs the oxygen from the film of lead oxide with which the lead is usually covered, thus making a clean and solid joint. The connecting straps are extended beyond the limits of the cell, and serve to connect the various cells of the battery, the connection being made by a lead-covered brass bolt in the case of small cells. Large cells are nearly always joined together by burning the connections.

TYPES OF LEAD-SULPHURIC ACID CELL

15. A great many different styles of storage cell of the lead-sulphuric acid type have been brought out both in North America and in Europe. The operation of all of them is substantially as described, their distinguishing features lying in the style of grid used and the methods of preparing or applying the active material. As it is impossible to here consider all the different types, we will confine our attention to a few of those that have been used most widely in America.

16. The Chloride Accumulator.—The Chloride accumulator made by the Electric Storage Battery Company is a type that is extensively used. Fig. 3 shows one of these cells in which the elements are mounted in a glass jar. The large cells used for central-station work are mounted in lead-lined wooden tanks. In the Chloride cell, the positive plate is of the Planté type and is known as the Manchester type of plate. The active material is formed from metallic lead. The negative plate is made by a special process. Fig. 4 shows the construction of the positive plate. The supporting grid *A* is a casting made of a mixture of lead and antimony and the holes in which the active material is placed are tapered from each side, as shown in the sectional view. This grid is not acted on by the acid and takes no part in the chemical changes that take place in the cell. It is strong mechanically, and serves to hold the active material *B* which is in the form of round plugs about $\frac{3}{4}$ inch in diameter, made by rolling up a corrugated ribbon of pure lead, as shown at (*b*); the

strip is slightly wider than the thickness of the supporting grid so that, when pressed in place, the plug projects a little on each side. The coiled-up piece of lead expands in the forming process, so that there is no possibility of its falling out. After the lead ribbon is in place it is converted into lead peroxide, as described, thus forming the active material. This construction gives a rigid plate, and, since the active material in each hole is free to expand and contract a certain amount, buckling is avoided.

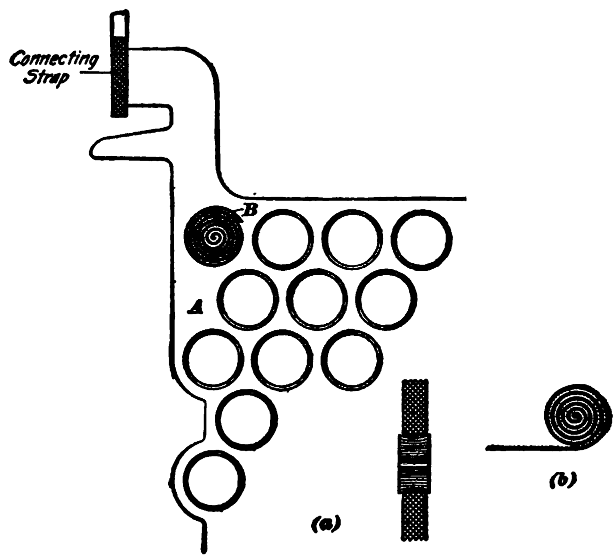


FIG. 4

The Chloride cell is so called because zinc chloride was at one time used in the construction of the negative plate. Though it is not used in the present type of plate the name is retained. Fig. 5 shows the construction of the negative plate known as the **box negative**. It is made of two parts *A*, *B* riveted together. Each part is made by casting lead-alloy ribs *c*, *c* on a sheet of perforated sheet lead; these ribs divide the sheet into a number of squares about 1½ inches each way. When the halves are riveted together, as shown in the sectional view, a number of small boxes, or recesses,

are formed; the halves are firmly held together by cast projections, at the rib intersections, that project from one half through corresponding holes in the other half. Before the halves are riveted together, the active material, litharge or lead monoxide, is placed in the recesses. The litharge is first made into a paste and molded into pellets, which are slowly dried. Four of these pellets are placed in each compartment of the plate, and as they fit in loosely they are free to expand and contract. The first charge given the battery after it is

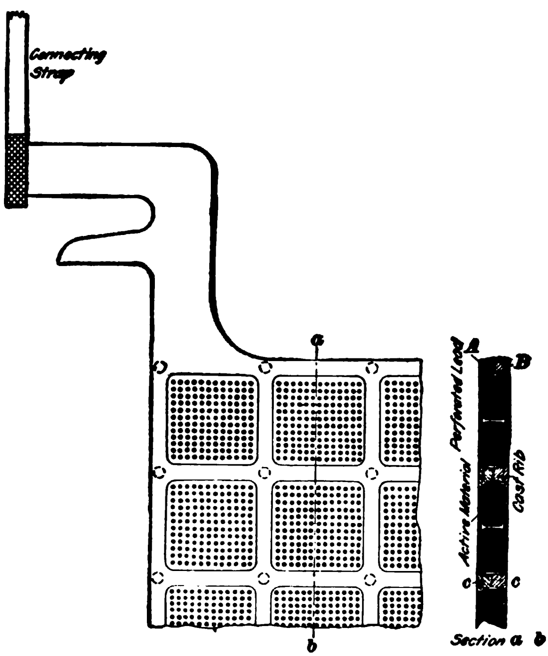


Fig. 5

installed converts the litharge into spongy lead, which constitutes the active material of the negative plate. This construction allows free access of the electrolyte to the active material and it is not possible for the latter to fall away from the plate as it did in some of the older types.

The requisite number of these prepared plates, positive and negative, are then set up together to form a cell, some

form of separator being usually placed between them. In the Chloride accumulator a number of different kinds of separators have been used. In the earlier cells the plates were separated by sheet asbestos, but the separator now generally used is a board diaphragm used in connection with wooden strips. The arrangement of these diaphragms and separators will be explained in detail in connection with the setting up of cells.

Fig. 6 shows the general arrangement of some large Chloride cells used with a central-station lighting system. Each cell here contains 87 plates 15½ in. × 32 in. The lugs *l*, *l* on the plates are burned on to the channel-shaped pieces *c*, *c* that form the connections between the cells; *d* is the edge of the lead lining of the tank; and *e*, *e* are glass rods formerly used for separating the plates. The heavy bar *m* forms one terminal of the battery and is connected to the last set of plates by means of the copper cross-piece *n*.

17. The E. M. F. and action of the Chloride accumulator are the same as that of the Faure (pasted) type or the Planté. It is claimed by the manufacturers that, from the solidity of the construction, buckling and loosening of the active material are practically impossible, so that the cells may be occasionally discharged to a low E. M. F. or at high rates without serious injury. Its output per pound of element is greater than that usually assigned to lead accumulators, being from 4 to 6 ampere-hours, according to the type of cell, per pound of plates (both positive and negative) at normal discharge rates.

18. The Gould Storage Battery.—The Gould battery is of the Planté type. Both positive and negative plates are made of rolled sheet lead, and the distinguishing feature of the cell is the method of increasing the active surface of the plates. Fig. 7 shows a Gould plate before it has been subjected to the forming process; the sheet lead is spun up so as to form thin ridges with grooves between them in which the active material is formed. Sheet-lead blanks are placed in steel frames and made to move back and forth between

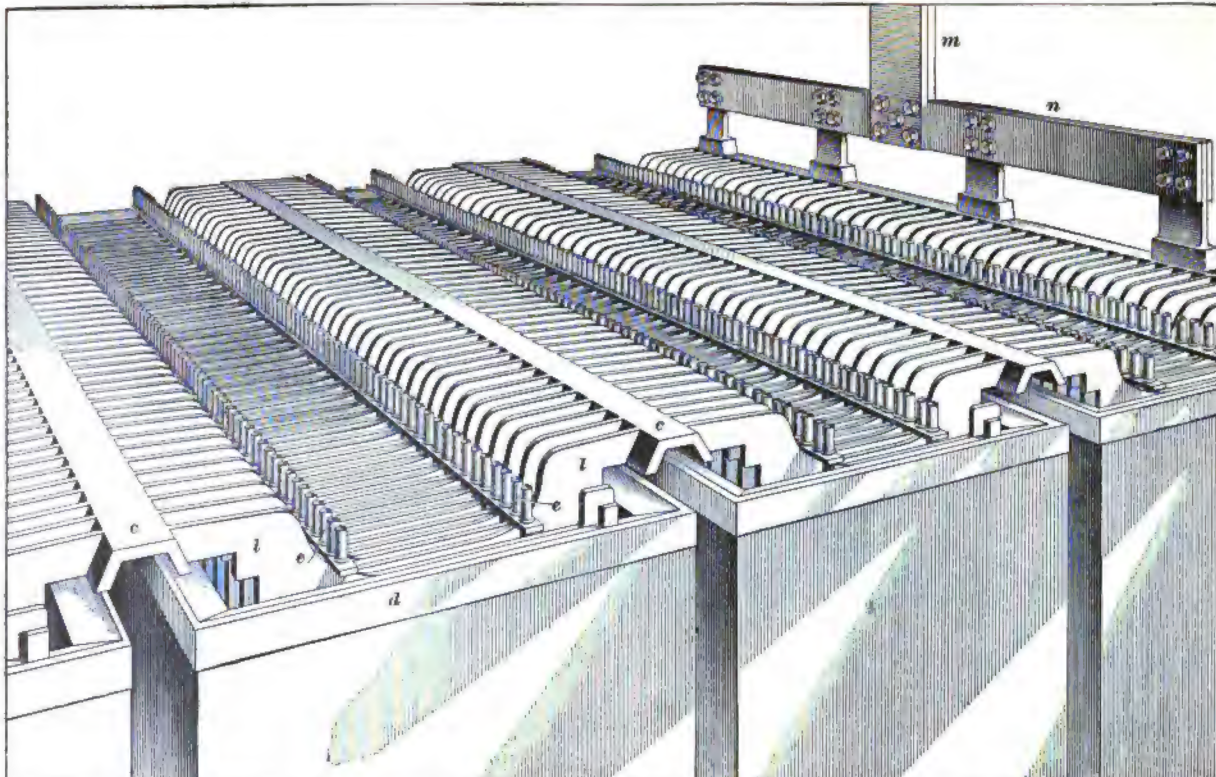


FIG. 6.

two rapidly revolving shafts on which are mounted steel disks alternating with steel washers. The thickness of the disks and washers determines the width of the grooves and the thickness of the ribs. The pressure maintained between

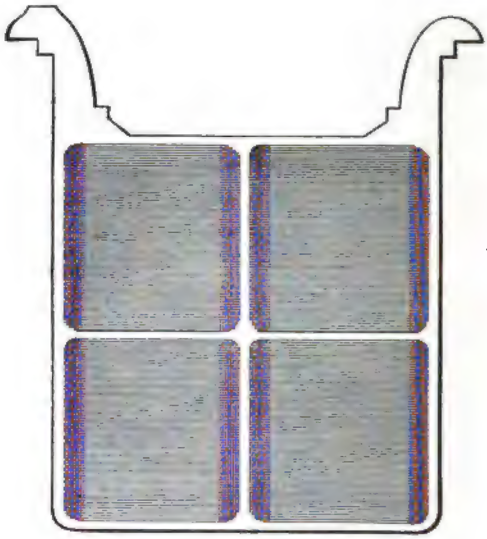


FIG. 7

the rolls and lead causes the latter to be spun up in thin ridges, as shown in Fig. 8 (*a*). No lead is removed from the blank; the form is merely changed so as to give a greatly increased surface. In all except the smallest plates the spun

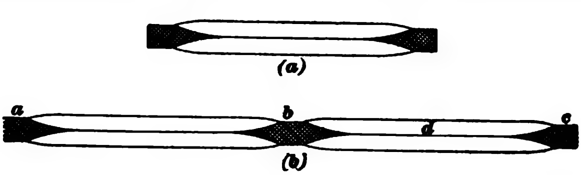


FIG. 8

portion is divided into sections, as shown in Fig. 8 (*b*), and the unspun parts *a*, *b*, *c* form bars of solid conducting material to which the thin webs are anchored. There is also a thin dividing line *d* in the center of the plate. The width of the

grooves is governed by the kind of work that the cell has to perform, and varies from .005 to .024 inch. By spinning up the lead, the superficial area is increased from ten to twenty times, and gives from 200 to 400 square inches per pound of lead. This permits a low current density at the contact surface between acid and plate, the density at normal discharge rate being about 1 ampere for each 250 square inches of contact

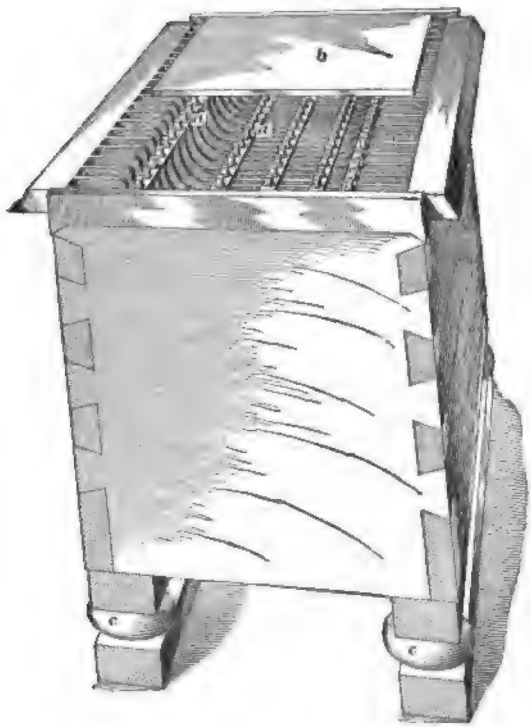
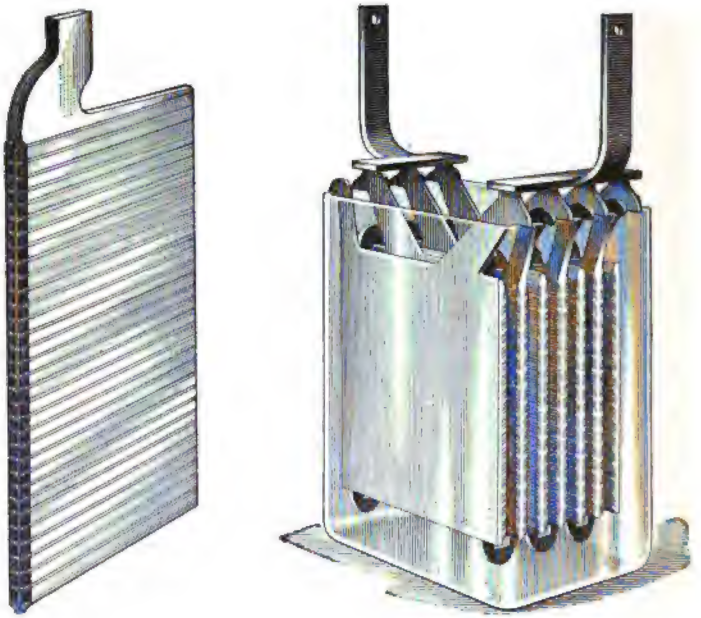


FIG. 9

surface. The thickness of the ribs varies from .005 to .040 inch on the positive plate, and is about .012 inch on the negative. The active material is formed electrochemically, and fills the narrow spaces between the ribs; these spaces are so narrow that there is little chance for the material to fall out. After the plates have been formed, the thin ribs do not appear as distinctly as shown in Fig. 7.

Fig. 9 shows a Gould cell arranged for central-station work. The elements are mounted in a lead-lined wooden tank, and are separated by glass rods *a*, *a*. This cell has 41 plates—20 positive and 21 negative—and has a capacity of 400 amperes for 8 hours, 560 amperes for 5 hours, or 800 amperes for 3 hours. It is covered by heavy glass, half of which *b* is shown in the figure, in order to prevent acid spray being thrown off when the battery gases. The whole cell is supported on porcelain insulators *c*, *c*.



(*a*) Fig. 10 (*b*)

19. The Willard Storage Battery.—The Willard battery is of the Planté type, the active material being held in narrow grooves cut in a rolled lead plate. Fig. 10 (*a*) shows a Willard plate; its grooves are inclined upwards in order to hold the active material more effectively in place. Fig. 10 (*b*) shows a complete cell of the Willard type. The action of the cell is the same as the Planté cell, so that further comment is unnecessary.

20. The foregoing will give a fair idea as to the construction of storage batteries. The list might be prolonged almost indefinitely, for many makes that are perfectly satisfactory in operation are not mentioned here. As before stated, nearly all of these cells operate on the same principle, the only difference being in the method of making the plates. A vast amount of time and money have been spent in the improvement of storage-battery elements and in perfecting the manufacturing details. The above, however, will be sufficient to show the general construction of such batteries as are made at the present time. It seems as if the Planté type were used most largely in America, especially for stationary work; in Europe, the Faure, or pasted type, is more common. The Faure type is used by some makers for automobile batteries, because, in general, the pasted cell gives a greater output per pound of weight than the Planté type. On the other hand, it has been found that pasted plates are more liable to disintegration, so that where weight is not an objection, the Planté type is favored.

AUTOMOBILE BATTERIES

21. In batteries intended for automobiles, electric launches, or similar class of service, every effort must be made to secure a large output with a minimum weight. The cells must at the same time have sufficient mechanical strength to withstand the jarring to which they are subjected. The grids used in these cells are of lighter construction than those used for stationary batteries and carry a larger proportion of active material.

Fig. 11 shows the general construction of the plates used in the "Exide" battery made for automobile use by the Electric Storage Battery Company. The foundation for the positive plate is a light but stiff cast grid made of a mixture of lead and antimony; the general form of the grid is indicated in Fig. 11 (*a*). These grids are pasted with red lead, which is afterwards converted into lead peroxide; the staggered arrangement of the cross-ribs, shown in the

sectional view, insures a firm locking of the active material. The negative plate, shown in (*b*), is of lighter construction than the positive. It is made up of a sheet of lead *a* with a stiff frame *b* cast around it. This sheet has a number of holes punched in it, half of these *c* being punched through from one side and the other half *d* from the other side. The metal is not removed but is torn or burred up as indicated. The torn projections are pressed down flush with the edge of the cast frame and the plate is then pasted on both sides with litharge, which is afterwards converted into spongy lead. The torn projections, when pressed down,

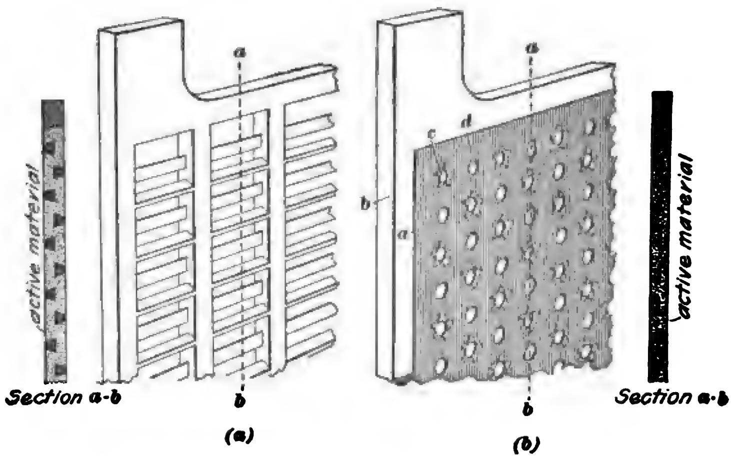


FIG. 11

form a series of hooks that lock the material securely to the plate. This cell is, therefore, of the Faure type, both plates being pasted.

The Porter automobile battery is also of the pasted type, while the Willard and Gould automobile batteries are of the Planté type, and have plates made in practically the same way as those used for stationary batteries. The elements of automobile batteries are usually mounted in hard-rubber cells in order to avoid breakage, and are separated from each other by perforated hard-rubber diaphragms. The output of automobile batteries is usually from 5 to 6.5 ampere-hours

per pound total weight when discharged at a 4-hour rate. However, it is difficult to compare such batteries simply by their capacity per pound weight. The ability to withstand rough usage and constant jarring is of more importance than mere lightness for this class of service.

BIMETALLIC ACCUMULATORS

22. Owing to the great weight of lead accumulators many attempts have been made to produce a storage cell that will be equal or superior to the lead cell and a great deal lighter. A vast amount of experimenting has been done along this line, but so far the lead cell has proved the most economical in the long run. In **bimetallic cells**, the elements consist of two metals, the electrolyte being a salt of one of the metals or a hydroxide. Though many combinations of metals have been proposed for these cells, the most satisfactory are the *zinc-lead*, *copper-lead*, *copper-zinc*, and, later, the *nickel-iron cell* of Edison. The principal trouble with bimetallic accumulators has been due to local action, which soon causes deterioration of the plates; also, many of these cells will not work well at ordinary temperatures, making it necessary to keep the electrolyte hot in order to secure satisfactory action. A few of these cells are described in order to show what has been done in this line, though few of them have been used to any great extent.

23. Zinc-Lead Cell.—The zinc-lead cell usually consists of plates of zinc and lead in a solution of zinc sulphate. On sending a charging current through this cell (the zinc being the negative plate) the zinc sulphate is decomposed, depositing zinc on the zinc plate and forming free sulphuric acid with the hydrogen of the water, which is also decomposed, its oxygen uniting with the lead plate, forming peroxide of lead. On open circuit and while charging, the free sulphuric acid in the solution slowly attacks the deposited zinc, reforming zinc sulphate, so that the efficiency of this form of cell is low; it will not retain a charge more than a few days. The E. M. F. is high, being about 2.35 volts to 2.5 volts.

By substituting copper sulphate for zinc sulphate, and copper plates for the zinc or other negative plates in this type of cell, the acid formed during charge cannot attack the copper, so that this loss is obviated; the E. M. F., however, is but 1.25 volts under these circumstances, so the watt output is materially reduced. Fig. 12 shows a zinc-lead cell made by the United States Battery Company. The positive element *a* is perforated lead, and the negative element *b* granulated zinc amalgam. The amalgam is placed in the bottom of the cell and the lead plate arranged horizontally above it in order to avoid short-circuiting by any particles that may drop off the positive plate; by thoroughly amalgamating the zinc it is claimed that local action is avoided. This type of cell gives an average E. M. F. about 15 per cent. higher than that of the lead-sulphuric acid cell, and is somewhat lighter. The electrolyte is a solution of zinc sulphate.

FIG. 12

Owing to the variations in the composition of the electrolyte, the internal resistance of these cells is variable, being lowest when charged and increasing during discharge as the sulphuric acid forms sulphate of copper or zinc.

24. Copper-Zinc Cells.—The copper-zinc accumulators were at one time in commercial use to a limited extent, the best known being the Phillips-Entz accumulator, made by the Waddell-Entz Electric Company. This accumulator employed the same active materials as the Lalande-Chaperon or Edison-Lalande primary cell, modified in mechanical construction to adapt them for accumulator use. The positive plate was made of porous copper on a solid foundation. The negative plate was a thin sheet of steel, and the plates were

mounted in a jar made of steel. The electrolyte was a solution of potassium zincate and potassium hydrate (caustic potash).

The reactions in a cell of this kind are complicated, but when the cell is charged zinc is deposited, from the potassium zincate, on the steel plates and the porous copper is oxidized. On discharge, the action is the same as in the Edison-Lalande primary cells; that is, the zinc is dissolved, the potassium zincate is reformed, and the copper oxide reduced to metallic (spongy) copper.

The efficiency of this type of accumulator is about the same as that of the lead accumulator, while its output is very much greater, weight for weight, the ampere-hour output being about five times that of a lead cell. The E. M. F. is much lower than that of the lead accumulator, averaging .75 volt during discharge, so that the comparison on a basis of watt-hour output is not so favorable; still, the copper-zinc accumulator will show an output of about 15 watt-hours per pound of plates, while the lead accumulators seldom exceed from 7 to 10 watt-hours per pound of plates, the latter figure being seldom reached at normal rates of discharge.

The efficiency and internal resistance of the copper-zinc accumulator vary quite largely with the temperature, on account of the considerable variations in the density of the electrolyte; on this account the cells are ordinarily charged and discharged at a temperature of about 54° C. (130° F.), at which point the resistance is about the same as in a similar lead accumulator.

These cells are not much affected by the rate of discharge, there being no such occurrence as sulphating or buckling; but on account of the difficulty of depositing the zinc in a solid form, the charging must be done at a low rate, and the action of the cells is improved by intermittent charging. The E. M. F. required to charge one of these cells varies from .9 volt at the start to 1.05 volts at the finish. On account of these features the copper-zinc accumulator can be used only in installations where it is charged and discharged daily, thus preventing local action, and when it can have the necessary appliances, care, and attention in charging, to

insure proper charging rate, temperature, etc.; so, in spite of its large output per unit of weight, it can hardly come into general use. Another serious objection to this type of cell is its low voltage; for a system operating at a given voltage nearly three times as many cells would be required as would be sufficient if lead-sulphuric acid cells were used. This objection, of course, applies to any cell that gives a low voltage. Like all cells using caustic potash or other hydroxide for the electrolyte, the air must be kept from the electrolyte to prevent the absorption of CO_2 (carbonic-acid gas) from the atmosphere, and the formation thereby of carbonates. The necessity of excluding the air by means of a layer of oil or by other means constitutes quite a serious drawback in the practical operation of these cells. Although this type of accumulator has many good points, it has never been able to displace the lead-sulphuric acid cell in commercial work on account of the above-mentioned drawbacks and has, in fact, never been used to any great extent.

25. Edison Nickel-Iron Cell.—A bimetallic cell has been developed by Edison that, it is claimed, is lighter and more durable than the lead type and does not have the disadvantages of other bimetallic cells. The cell has been developed with particular reference to the requirements of electric vehicle service, but at present it has not been used to a sufficient extent commercially to indicate whether or not it will be able to displace the lead type of cell. The active material of the positive plate is peroxide of nickel and that of the negative plate, finely divided iron. Both plates are constructed as indicated in Fig. 13. The active material is held in flat stamped steel boxes, or pockets, made by shallow halves that fit tightly together. These boxes are perforated with narrow slits that allow the electrolyte to come in contact with the material contained within. The plate proper is made of steel, nickel plated, and is punched with twenty-four rectangular openings, as shown at *a*, Fig. 13. The boxes *b* are held in the openings as shown in the complete plate *c*. The plates are quite thin and the number required for a cell

are assembled with rubber separators between adjacent plates. The electrolyte is a 20-per-cent. solution of caustic potash (KOH), and as the amount required for the cell is small, the plates can be placed close together. The nest of plates is placed in a sheet-steel containing vessel. The regular automobile cell measures 13 in. × 5.1 in. × 3.5 in. and weighs

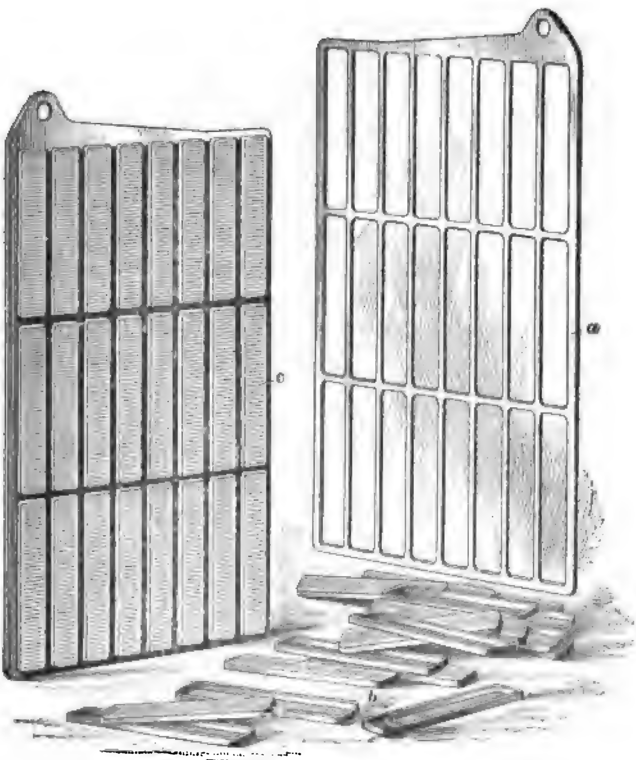


FIG. 13

17.8 pounds. The E. M. F. of the cell is 1.33 volts, and the output varies from 173 to 142 ampere-hours on discharges ranging from 30 amperes to 200 amperes. This corresponds to about 13 watt-hours per pound at the lower discharge rate. Like all other cells using a hydroxide for the electrolyte, the air must be excluded to prevent the formation of carbonates.

INSTALLATION AND CARE OF STORAGE CELLS

SETTING UP CELLS

26. The following instructions regarding the installation and care of storage cells are an abstract of those furnished by the Electric Storage Battery Company, and refer to the Chloride cell as used for stationary work. However, the instructions may be taken as applying for the most part to any of the ordinary types of lead-sulphuric acid cell. Manufacturers send out instructions regarding their cells and give any special recommendations that may relate to their particular type. For the most part these instructions apply also to automobile or other portable cells.

27. Location.—Storage cells should be located in a well-ventilated room of moderate temperature, say from 50° to 75° F. The floor should be of cement with drainage facilities, and the room should be light enough to allow easy inspection of the cells. Generally, the battery room is located somewhere near the dynamo room in case the battery is used in connection with a central station, as a near-by location cuts down the length of conductors between the battery and station, and also allows the outfit to be watched to better advantage.

28. Method of Supporting Cells.—The cells are usually mounted on racks made of heavy wooden framework securely braced. It must be remembered that these cells are heavy, and sagging of the framework is not allowable, as it may result in broken cells. If there is plenty of space available, the cells should be in a single tier, in which case all the framework that is necessary is a set of stringers properly

fastened together. Fig. 14 shows a framework recommended by the Electric Storage Battery Company for those places where it is necessary to arrange the cells in two tiers. Each cell is placed in a shallow wooden tray *a* partly filled with sand, and each tray is set on four single petticoat glass insulators. The sand distributes the strains on the glass jar and avoids breakage. Where wooden tanks are used, these trays are not necessary. Fig. 15 shows the shape of the glass insulators. Any current leakage from the cells has to take place over the petticoat *a*, taking the long path indicated by the dotted line.

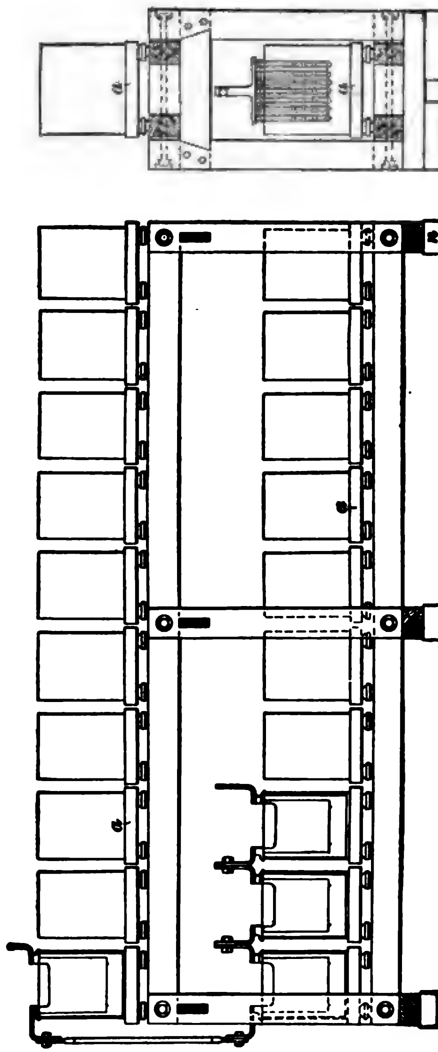


FIG. 14

29. Placing Elements in Jar.—The elements and jars are shipped separately, so that the battery usually has to be assembled at the place where it is to be used. The plates should be unpacked carefully, because if handled roughly they may be bent or

otherwise damaged. The positive and negative plates are, except in the case of very large cells, connected together in groups; the positive group is easily distinguished by its dark-brown, color. Fig. 16 shows the various parts of a Chloride accumulator after they have been unpacked and separated; *a* is the negative group, *b* the positive, *c* the jar, *d* the wood diaphragms for placing between the plates, *e* the slotted wood separators for slipping over the diaphragms and holding them up in place, and *f* one of the diaphragms with its pair of slotted wood separators in place. The block *g* is used in mounting and arranging the elements and the lead-covered brass screws *h* are for bolting the terminals of the cell

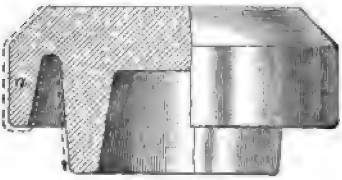


Fig. 15

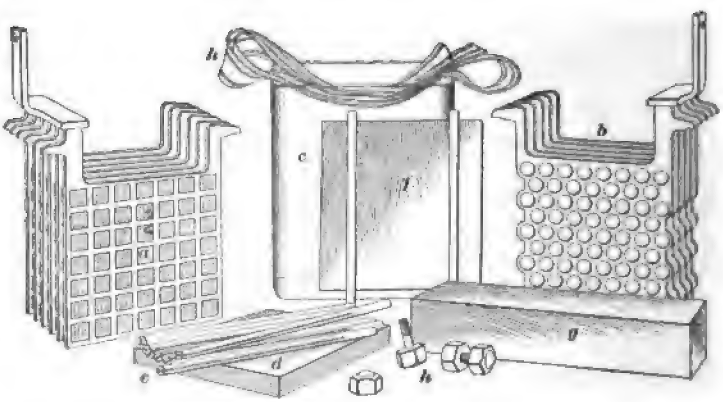


Fig. 16

together. Before placing the board diaphragms between the plates, the grain of the wood always being parallel to the edges or sides of the plates, two of the slotted wood separators must be slipped over each board and spaced $1\frac{1}{4}$ inches from the edge. The elements are then slipped together, as shown in Fig. 17 (*a*), and the diaphragms adjusted in place. The whole group of elements is then lifted, by means of a broad piece of webbing, on to the block mentioned above.

This allows the diaphragms to be pushed down into place, and the elements further adjusted, as shown in Fig. 17 (*b*). The elements are then lifted by means of the webbing, as shown in (*c*), and gently lowered into the jar.

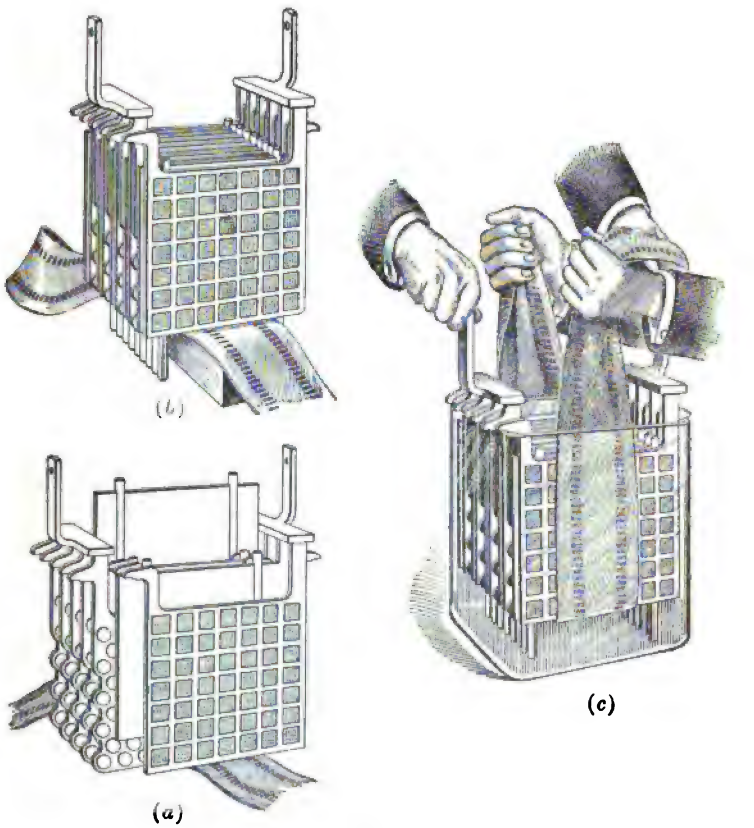


FIG. 17

Though this method of placing plates refers particularly to the Chloride accumulator it can be used with almost any of the ordinary types of storage cell. After the cells have been assembled the lead terminals should be well scraped at the point where they are bolted together in order to secure good electrical contact.

THE ELECTROLYTE

30. Mixing the Electrolyte.—The **electrolyte** used in storage batteries differs slightly with different makes of cell; it is always dilute sulphuric acid, but the specific gravity of the solution recommended by different manufacturers varies somewhat. The electrolyte should have a specific gravity of 1.20 to 1.24, as indicated by the hydrometer when the cells are charged. The specific gravity is taken at normal temperature of about 60° F. Most manufacturers of storage cells furnish electrolyte ready mixed, but it can be prepared by diluting suitable commercial sulphuric acid (oil of vitriol) with pure water. In selecting sulphuric acid none but the sulphur or brimstone acid should be used; acid made from pyrites is liable to contain impurities, such as iron or arsenic. It is absolutely essential that the acid and water be free from impurities, such as iron, arsenic, and nitric or hydrochloric acid. When diluting, the acid must be poured slowly and with great caution into the water; do not pour water into the acid because the sudden evolution of heat and the consequent boiling action may throw acid into the operator's face. The proportions of acid (of 1.84 specific gravity or 66° Beaume) and water are 1 part of acid to 5 of water (by volume). The vessel used for the mixing must be a lead-lined tank, or one of wood that has not been used for other purposes; a wooden wash tub or spirits barrel answers very well. The electrolyte when placed in the cell should come ½ inch above the top of the plates. Before putting the electrolyte in the cells, the circuits connecting the battery with the charging source should be complete. The positive pole of the charging source must be connected to the positive pole of the battery. Also, care must be taken in placing the cells to see that positive and negative poles of adjacent cells are connected together. It is an easy matter to connect one or more cells backwards if the terminals are not closely inspected when the cells are being connected. After the electrolyte has been placed in the jars, the battery should be charged at once, if possible; in any event, the cells

should never be allowed to stand more than 2 hours after the electrolyte has been placed in them, before they are charged. The value at which the density of the electrolyte should be maintained is usually specified by the manufacturer, but it is generally in the neighborhood of 1.2; automobile batteries are usually supplied with an electrolyte having a slightly higher density. During regular operation of the battery, the density of the electrolyte changes; as the battery is charged the specific gravity rises until it reaches a maximum not necessarily fixed; when the battery is discharged the specific gravity lowers. The acid does not evaporate so that any evaporation of the electrolyte should be made up by the addition of water; however, a certain small amount of acid may be thrown off in the form of fine spray or be absorbed by sediment in the bottom of the cell. The addition of some acid every 1 or 2 years is, therefore, necessary in order to maintain the specific gravity at the standard density. The most convenient way of adding the acid is to prepare a mixture of acid and water having a density of about 1.4, and add as much of this as may be necessary. As mentioned above, it is particularly important that the acid be free from impurities; if there is any doubt on this score a sample should be analyzed. As the proper performance of a battery depends very much on the condition of the electrolyte, hydrometer readings should be taken at regular weekly intervals.

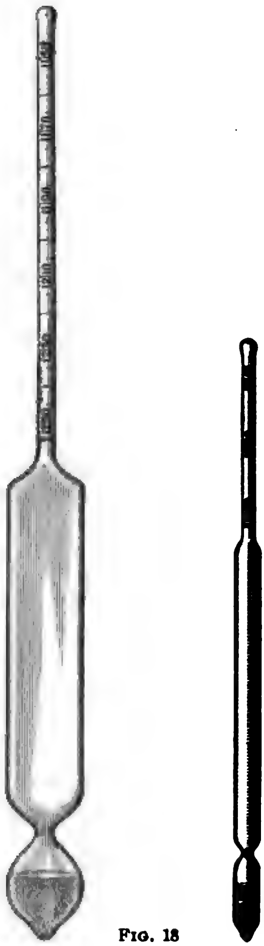


Fig. 18

31. Hydrometers.—In order to facilitate the determination of the density of the electrolyte, special forms of **hydrometers** are used in connection with storage-battery work. Fig. 18 shows two styles of battery hydrometer suitable for use in stationary cells where there is plenty of room around the plates for placing the hydrometer in the liquid. The larger size is preferable, as the density can be determined more easily and more closely than with the smaller, which is only used in cells where there is not sufficient room for the larger size. Each of the hydrometers has a small bulb at the lower end and that contains a quantity of fine shot. Some hydrometers have mercury in the bulb, but shot is preferable because, if the bulb becomes broken, no mercury as an impurity is introduced into the electrolyte. Moreover, if mercury gets into a lead-lined tank it attacks the lead lining or rather amalgamates with it and a leak is likely to result. The air in the large bulb floats the hydrometer, which, when placed in the electrolyte, stands upright, and the reading on the stem is taken at the point where it emerges from the liquid.

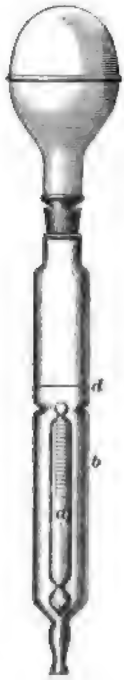


FIG. 19

Fig. 19 shows a style of hydrometer more particularly adapted to cells where it would be difficult to place a hydrometer directly in the liquid, as, for example, in automobile batteries. The hydrometer *a* is placed within the glass tube *b*, and by means of the rubber bulb sufficient electrolyte can be drawn up to float the hydrometer. Enough liquid is drawn up to fill the tube up to the mark *d* ground on the glass, and the reading is taken at the point where the floating tube *a* emerges from the liquid.

NOTE.—The hydrometers generally used with storage batteries indicate directly the specific gravity of the solution. Some hydrometers are graduated with the so-called Baumé scale, in which the density of water is considered as 1° and that of concentrated sulphuric acid as 65°. The proper density of the acid for storage cells when charged is 25° on the Baumé scale.

CHARGING

32. After the battery has been set up, it should be given a full charge at the normal rate. The rate of charging is usually the same as the 8-hour rate of discharge as specified by the manufacturers. It is desirable that the charging be continued uninterruptedly, though this is not absolutely essential. The charge should be continued until it is certain that the charging is complete according to the signs given below. It should not be repeatedly carried beyond the full-charge point, because it entails an unnecessary waste of energy, causes a rapid accumulation of sediment, wastes acid through spraying, and what is still worse, shortens the life of the plates. It is advisable to overcharge the batteries slightly, about once a week, in order that the prolonged gassing may thoroughly stir up the electrolyte, and also in order to correct any inequality in the voltage of the cells that may have developed. At the end of the first charge it is advisable to discharge the battery about one-half, and then immediately recharge it. Repeat this operation two or three times, and the battery will then be in condition for regular use.

33. Indications of a Complete Charge.—A complete charge should exceed the previous discharge, in ampere-hours, from 12 to 15 per cent. The principal indications of a complete charge are: (1) The voltage and specific gravity reach a maximum value, which value is not necessarily fixed; for example, the voltage at the end of a charge may be from 2.4 to 2.7. (2) The amount of gas given off at the plates also increases when the cells are fully charged. (3) The positive plates become a dark brown, and the negatives a light gray. (4) With all the cells of the battery in normal condition, with pure electrolyte and no material lodged between the plates or sediment touching them at the bottom, the maximum voltage and specific gravity are reached when, with the charging current constant at the normal rate, there is no further increase in either during a period from $\frac{1}{4}$ to $\frac{1}{2}$ hour; for example, if the charge has been

carried on for 5 hours with a gradual rise in the voltage and specific gravity during that time and with an additional ½ hour of charging, there should be no further rise in either, then the charge is complete.

34. Voltage at End of Charge.—The voltage at the end of a charge is not always the same. It depends on the age of the plates and the temperature of the electrolyte; hence, both of these must be taken into consideration when determining the completion of a charge. When the battery is first installed, the voltage at the end of the charge will be 2.5 volts per cell or higher, at normal rate of charge and at normal temperature. As the age of the battery increases, the point at which it will be fully charged is gradually lowered and may drop as low as 2.4 volts at normal rate and temperature. With charging rates lower than the normal, the voltage at the end of the charge will be approximately .05 volt less for each 25 per cent. decrease in the rate. For example, if the final voltage were 2.50 at the normal rate, say, of 1,000 amperes, it would be 2.45 at 750 amperes, and 2.40 at 500 amperes. If the temperature is increased above normal, the final charging voltage is noticeably lowered, and vice versa, irrespective of the age of the plates. It is understood in the preceding that all voltage readings are taken with the current flowing; readings taken with the battery on open circuit are of little value and are frequently misleading. After the completion of a charge and when the current is off, the voltage per cell will drop to about 2.15 volts and then to 2 volts, or slightly less, when the discharge is started. If the discharge is not begun at once, the pressure will quite rapidly drop to 2.05 volts and remain there while the battery is on open circuit. Cells should never be charged at the maximum rate except in cases of emergency; if charged at the maximum rate, the final voltage per cell will be about .05 volt higher than if charged at normal rate.

DISCHARGING

35. One of the most valuable features of a storage battery is its ability to deliver large currents for short intervals. While such is the case, repeated heavy overdischarges are almost sure to injure the cells if maintained for a considerable time. Batteries should, therefore, be discharged at about the normal rate as nearly as possible. The amount that a battery has discharged can be determined in the same manner as the amount of charge, i. e., from voltage and specific-gravity readings. During the greater part of a complete discharge the drop in voltage is slight and very gradual until near the end, when the falling off becomes much more marked. The limit of discharge is reached when the voltage has fallen to 1.7 volts per cell; a battery should never be discharged below this point, and in ordinary service it is advisable to stop the discharge considerably above it. Cells, as a rule, are not discharged below 1.75 volts, and 1.7 represents the limit that should not be passed under any circumstances. If a reserve is to be kept in the battery for use in case of emergency, the discharge must be stopped at a correspondingly higher voltage. The fall in density of the electrolyte is in direct proportion to the ampere-hours taken out, and is, therefore, a reliable guide as to the amount of discharge. In this respect it differs from the drop in voltage, which varies irregularly for different rates of discharge; consequently, the specific gravity of the electrolyte is the more satisfactory guide. The actual amount of variation in the strength of the electrolyte between full charge and full discharge depends on the quantity of solution compared with the bulk of the plates in the cell. If a cell contains the full number of plates, the change in specific gravity is about 35 points. With fewer plates in the same size containing vessel, the range will be lessened. Also, at higher rates of discharge than normal the drop in specific gravity will be less because of the smaller number of ampere-hours discharged. As the discharging progresses, the positive plates become somewhat lighter and

the negatives darker, so that the color of the plates is a rough indication of the amount of discharge.

After a battery has been completely discharged it should be immediately charged again. It should be allowed to stand but a very short interval, if at all, before recharging.

MISCELLANEOUS POINTS

36. Inspection of Cells.—In order to secure satisfactory operation of a battery each of the cells should be inspected at regular intervals. The voltage of individual cells may become low, the electrolyte may not be of the proper specific gravity, or foreign substances may become lodged between the plates or in the bottom of the cell, and regular inspection is necessary to locate any such defects that may develop. Such readings as are taken from the cells should be recorded in such a way that consecutive readings can be easily compared; if a cell is acting irregularly, the fact will then be at once apparent. Each cell should be thoroughly inspected at least once a month. This can be easily done by examining a certain number of cells each day in case the battery is too large to examine all the cells in a single day.

For the inspection of individual cells, a portable lamp should be used so that any tendency for an accumulation or lodgment of material between the plates can be at once noticed. If the elements are in glass jars, an ordinary lamp with extension cord will be found most convenient; by holding the lamp behind the jar and looking through between the plates, the condition of the cell can at once be seen. If wooden tanks are used, a lamp suitable for immersion to the bottom of the electrolyte will be needed. When examining a cell great care should be taken to look between all the plates, and any accumulation of material should be removed at once. If the accumulation is from the plates themselves, it may be pushed down to the bottom of the containing vessel by means of a stick of hard rubber or wood; if it is any foreign substance it should be removed from the cell. A

metal rod should never be used for removing obstructions in a storage cell; it is sure to cause short circuits and do damage.

In addition to the examination of the cells with the lamp, an examination should be made near the end of each charge to see if all the cells are gassing equally, and readings of voltage and specific gravity should be taken at the end of a prolonged charge, while the current is still flowing. If any of the cells show readings lower than normal and do not gas freely at the end of the charge, they should be examined at once with a cell lamp to determine the cause of the falling off. Very likely it is due to short-circuiting between the plates, caused either by a lodgment of material in the intervening space or else by an accumulation of mud in the bottom of the cell.

37. It is advisable, in storage-battery installations, to use recording instruments to show the variations in voltage or current. There are many types of these instruments, but in most of them a paper chart is moved at a uniform rate by means of clockwork and on it the pointer of the ammeter or voltmeter draws a line showing the variations in voltage or current. Sometimes the record is made on a straight strip of paper but more often it is made on a circular chart, as in the Bristol recording instruments. Records of this kind are valuable because they show just what the battery has been doing; and if it is not performing satisfactorily, steps can at once be taken to remedy the defect. The most generally useful instrument is a recording voltmeter. Recording wattmeters are sometimes used where the expense is warranted. A special type of Thomson recording wattmeter is made for this purpose. The instrument is provided with two recording dials, one of which is moved by the meter mechanism when the battery is charging and the other when it is discharging. The amount of charge given to the battery during any given period can thus be compared with the amount of discharge and the watt-hour efficiency thereby determined.

38. Getting Low Cells Into Normal Condition.—A cell that has become low will generally require more than the usual amount of charging to get it into condition again after the cause of the trouble has been removed. The simplest way of doing this is to overcharge the whole battery until the low cells are brought up to the proper point, but care must be taken not to carry this to excess. Another method is to cut the low cells out of circuit over one or two discharges, and then cut them in on the charges. A third method is to give the faulty cells an individual charge while the other cells are on the discharge; the most convenient way of doing this is by means of a small motor-driven dynamo. Before putting a cell that has been defective into service again, care should be taken to see that all the signs of a full charge are present.

39. Sediment in Cells.—After cells have been in service for some time there is an accumulation of sediment in the bottom caused by small particles dropping from the plates. This sediment should never be allowed to touch the bottom of the plates and thus short-circuit them; it should be carefully watched, especially under the middle plates, as it accumulates there more rapidly than under the side plates. If there is any free space at the end of the cells, the sediment can be raked from under the plates and then scooped up; the device used for this purpose must have no metal in its make-up. If this method is impracticable, the electrolyte should be drawn off into clean containing vessels after the battery has been fully charged. The cells should then be thoroughly flushed with water, from the local water supply, in such a way as to stir up the sediment thoroughly and get it out of the cells. All the water should then be drawn off; if the cells are too low for siphoning, a rotary pump with bronze parts should be used. After the cells have been thoroughly cleaned, the electrolyte should be at once replaced before the plates have had a chance to become dry, and thus necessitate the long charge required by dry plates. In addition to the electrolyte withdrawn, new electrolyte must be added to make

good that displaced by the sediment; this should be of 1.3 or 1.4 specific gravity to counteract the effect of the water absorbed by the plates during the washing process, and also to reduce the bulk of the new supply. The electrolyte must be kept free from impurities; if it is known that any impurity, especially any of the metals other than lead, or other acid has got into a cell in any except very minute quantities, the electrolyte should be renewed immediately.

40. Battery Used Occasionally.—When the battery is used but occasionally, or if the discharge is at a very low rate, the battery should be given a weekly freshening charge.

41. Putting Battery Out of Commission.—If the use of the battery is to be discontinued for a considerable time, say 6 months or more, it is usually best to take it entirely out of service by withdrawing the electrolyte. This should be done as follows: After giving a complete charge, siphon off the electrolyte into convenient receptacles, preferably carboys that have previously been cleaned and have never been used for other kinds of acid. As each cell is emptied, immediately refill it with water. After water has been placed in all the cells, begin discharging and continue until the voltage falls to or below 1 volt per cell at normal load. Then draw off the water; the battery may then stand without further attention until it is needed again.

42. Putting Battery Into Commission.—To put a battery into commission proceed in the same manner as when giving the battery its first charge. First make sure that the polarity of the charging source has not been altered during the interval that the battery has been out of use, and that the positive pole of the battery connects to the positive pole of the charging source. Put in the electrolyte and begin charging at once at the normal rate, and continue until the charge is complete; from 25 to 30 hours at this rate will be required.

43. Cadmium Test.—It may sometimes happen that the plates of a cell are unevenly acted on; that is, the material on one plate may be wholly changed during the charge,

while that on the other plate may be only partially changed. When the cell is discharged, it is evident that under these conditions the voltage will fall off sooner than it should because the capacity of the cell will be limited by the capacity of the partially converted plate. In order to determine the existence of such a condition it is necessary to test each of the plates separately because the voltage of the cell as a whole will not indicate the relative condition of the plates. In order to make the test, a third electrode, consisting of a piece of cadmium, is used; a piece of zinc could be used if it were chemically pure. The cadmium test piece is dipped into the electrolyte and the voltage between it and the plates of the battery measured by means of a low-reading voltmeter. Care should be taken to see that the cadmium is not allowed to touch either plate. If both plates are fully charged, and the normal charging current flowing through the battery, the voltage between the positive and negative plates will be about 2.45 to 2.5 volts. The voltage between the cadmium and the negative plate will be about .18 or .19 and between the cadmium and positive plate about 2.3 volts, the voltage of the cell being the sum of the two readings. When the battery has been discharged until the voltage per cell is reduced to 1.8 or 1.75 volts, the voltage between the cadmium test piece and the positive plate will be about 2.05 and between the cadmium and negative about .25, the voltage of the cell being the difference of the two readings. When the cell is fully discharged, the cadmium is positive to both plates; when it is fully charged, the cadmium is positive with regard to the positive plate and negative with regard to the negative plate. All the readings given above and the statements regarding the polarity of the cadmium with respect to the plates assume that the normal charging or discharging current is flowing when the readings are taken.

44. Sulphating.—Unless a battery is properly looked after, **sulphating** is liable to set in, and if allowed to go too far may cause a great deal of trouble. As already explained, lead sulphate, $PbSO_4$, is formed during each discharge of a

cell. This sulphate does no harm; in fact, it is essential to the operation of the cell. However, under certain conditions a white insoluble sulphate, Pb_2SO_4, may be formed, and it is this that is credited with the action known as *sulphating*. When a cell is sulphated, the plates, more particularly the positive, become covered in spots with this white insoluble sulphate, which is difficult to remove. As the sulphate usually accumulates in patches and as it prevents, to a large extent, chemical action on the active material underneath it, the capacity of the cell is reduced and the uneven action is liable to lead to buckling unless the mechanical structure of the plate is such that buckling is practically impossible. The most frequent causes of sulphating are overdischarging, wrong specific gravity of electrolyte, and allowing the battery to stand for a considerable length of time in a discharged condition; if a battery is looked after, as it should be, there will be little trouble from this source. If cells are repeatedly discharged below 1.7 volts, sulphating may be expected; too strong an electrolyte will also cause it. At the end of a complete charge, a lodgment of white powder that may easily be brushed off will sometimes be noticed on top of the plates; provided the body of the plates is the proper color, no attention need be paid to this powder as it is composed of particles from the plates thrown off by the gassing at the end of the charge; these particles become sulphated and of a light color while in suspension in the electrolyte.

In case white insoluble sulphate appears on the plates, the battery should be given a long continued charge at a low rate, somewhat below the normal 8-hour rate until the cells give all the signs of a full charge, and the plates have resumed their normal color. In case of badly sulphated cells, the color of the positive becomes lighter than normal and the negatives considerably darker.

45. Treatment of End Cells.—In order to allow the voltage of a battery to be varied, a number of cells at one end are frequently arranged so that they may be cut into or out of circuit. These are called **end cells.** Owing to the

fact that these cells are cut in and out of circuit, they are specially liable to become unevenly discharged and, therefore, require more attention than the remainder of the cells. They are successively cut into service on the discharge; hence, on the charge they should be successively cut out in the reverse order, otherwise the ones that were last cut in will be overcharged. Special care should be taken in regard to this, as it is easy to forget that a number of the cells were not cut into circuit until probably near the end of the discharge, and thus require but a small proportion of the amount of charge required for the main battery. As an aid in determining the state of charge of the end cells, there is usually installed on the switchboard a multi-circuit voltmeter switch by which the voltage of each end cell can be obtained. If any of the end cells are not used regularly or stand idle, they should be given a complete charge once a week.

SIMPLE CONNECTIONS FOR CHARGING

46. Where cells are used for portable purposes it is necessary to provide some convenient means for charging them from the ordinary sources of electrical supply. The best method of doing this will depend on the available source of charging current. It goes almost without saying that alternating current, as such, cannot be used for charging a battery, and when it is the only available source, some means must be provided for changing it to direct either by means of an alternating-current motor coupled to a direct-current dynamo, or by a rotary or mercury-vapor converter. If the ordinary 110-volt, direct-current, lighting circuit is available, it is an easy matter to charge the cells as indicated in Fig. 20 (*a*). A double-pole switch *a* with fuses *b* is connected between the mains and the battery as shown. In series with the battery *c* are a number of lamps by means of which the charging current is limited to the proper amount. It is advisable to connect an ammeter *d* in circuit, though this is not absolutely necessary. The number of lamps required depends on the line voltage and on the charging rate of the

cells. If the line pressure is 100 to 120 volts and but three or four cells are to be charged with a current of 5 amperes, then five 32-candlepower lamps connected as in Fig. 20 (*a*) will be sufficient. If 16-candlepower lamps are used, it will

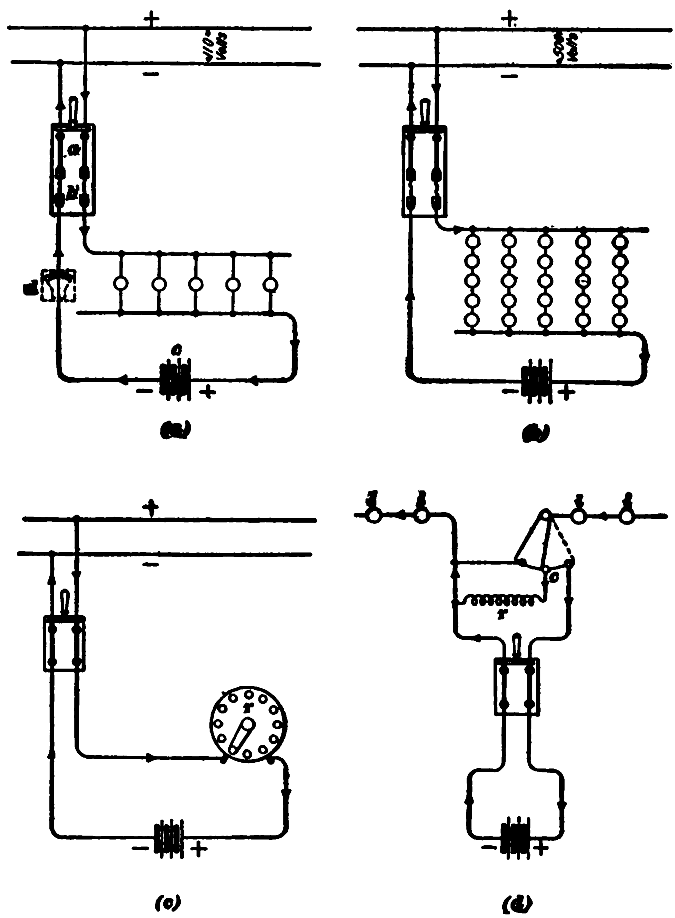


FIG. 20

be necessary to connect ten in parallel. If the line pressure is 500 volts it will be necessary to connect twenty-five 32-candlepower lamps in five rows of five lamps in series in each row, or fifty 16-candlepower lamps in ten rows, five

lamps in series in each row as shown in (*b*). In case it is convenient to charge at a lower rate, fewer lamps will be needed, but the time for charging will be proportionately increased.

Lamps form a convenient resistance as they are easily obtained, but an adjustable rheostat r is frequently used, as shown in (*c*). The amount of resistance required in the rheostat can be easily obtained as follows: Let N be the number of cells to be charged in series, then $2N$ will be the approximate voltage for charging, since each cell may be taken as requiring 2 volts at the beginning of the charge. If E is the line E. M. F., then $E - 2N$ is the number of volts effective in forcing current through the circuit, because the E. M. F. of the cells is opposed to that of the line. If I is the charging current, then the resistance of the circuit will be

$$R = \frac{E - 2N}{I} \qquad (1)$$

and this will be practically equal to the amount of resistance required in the rheostat, because the resistance of the cells is very low.

EXAMPLE.—Twenty storage cells are to be charged from a 220-volt circuit. How much resistance should be connected in series with them if the charging current is to be 5 amperes?

SOLUTION.—From formula **1**, $E = 220$, $N = 20$, and $I = 5$; hence,

$$R = \frac{220 - 2 \times 20}{5} = 36 \text{ ohms. Ans.}$$

This resistance should be adjustable so that some of it can be cut out as the voltage of the cells increases, and it must be made of wire large enough to carry at least 5 amperes without overheating.

Charging with resistance in series is at best a makeshift because it involves a large loss of energy; as a rule, it is used only where a few cells are to be charged and where no other method is available. A resistance is not used with regular batteries because the number of cells is such that the battery can either be connected directly across the charging circuit or else used in connection with a booster in power or lighting stations or with motor generators in

telephone or telegraph stations. The use of a resistance involves a waste of energy, but in the case of small portable batteries this waste is not a very serious matter, especially as the use of the series-resistance gives the most convenient and simple means of charging from existing circuits.

47. Charging From Constant-Current Arc Circuit. Sometimes cells are charged from constant-current arc-light circuits, but the practice is dangerous and this source of charging current should never be used if any other is available. Constant-current arc-light dynamos generate a very high pressure, and as arc-light lines are nearly always grounded to a greater or less extent, there is quite an element of danger in working around a battery that is being charged from such a source. Great care must be taken to see that the arc-light circuit is not opened when the battery is being switched on and off. This method of charging is shown in Fig. 20 (*d*), where *l*, *l* represent arc lamps. In this kind of circuit the current is maintained at a constant value, usually from 6 to 10 amperes, so that when the battery is to be charged it must be placed in series with the lamps. The battery is cut into circuit by means of a special switch called a *consumer's switch*, which is constructed so that it will neither open the circuit nor short-circuit the battery. This is done by means of a contact point *c* connected to a resistance *r*. When the broad blade is moved to the dotted position, the resistance is first placed in series so that the line is not opened, and at the same time there is no short-circuiting of the battery. It will be noticed that when the switch is in the dotted position, the resistance is in parallel with the battery so that part of the main current is shunted around the battery. For example, the main current might be 9 amperes and the required charging current 5 amperes, in which case the resistance should be such that the difference between the two, i. e., 4 amperes, will flow through it. The pressure between the terminals of the resistance is equal to the E. M. F. of the cells; hence, if I is the current shunted through the resistance, E the voltage of

the series of cells, and R the resistance, then R is easily obtained from the relation $R = \frac{E}{I}$.

48. Direction of Current.—When charging a battery from any source, especially when there is any doubt as to the direction of flow of the current, a test should be made to determine whether or not the positive plates are connected to the positive pole, so that the current flows in at this pole when the battery is charging. A simple method of doing this is to attach two wires to the mains, connect some resistance in series to limit the current, and dip the free ends into a glass of acidulated water, keeping the ends about 1 inch apart. The end from which bubbles of gas are given off most freely is connected to the negative main, so that the main to which the other end connects is the one to be attached to the positive pole of the battery. Another convenient method of testing the polarity is by means of a Weston voltmeter, or instrument of similar type, which will give a deflection over the scale only when the terminal marked + is connected to the positive line.

49. Battery Charged From Dynamo.—Fig. 21 shows about the simplest possible arrangement of connections for charging a storage battery from a dynamo, all appliances that are not absolutely necessary having been left out in order to avoid confusion. A is a dynamo, usually either of the shunt-wound or compound-wound type; f is the rheostat in the shunt field, by means of which the voltage of the machine may be varied through a considerable range; V is a voltmeter connected to the voltmeter switch S, which is so arranged that the voltmeter may be connected to either the battery C or the dynamo A; E is a double-pole knife switch, by means of which the battery may be thrown in connection with the dynamo; F is an ammeter that shows the amount of the charging current. The ammeters used with storage batteries are usually made with their zero point at the middle of the scale. When the battery is charging, the needle is deflected to one side of the zero mark; when discharging,

it is deflected to the other side, thus showing at a glance which way the cells are acting. It should be noted that the + side of the dynamo is connected to the + side of the battery when the switch is thrown in, the direction of the charging current being indicated by the arrows. In this case, we have assumed that the number of cells to be charged is sufficiently great to take up the voltage of the

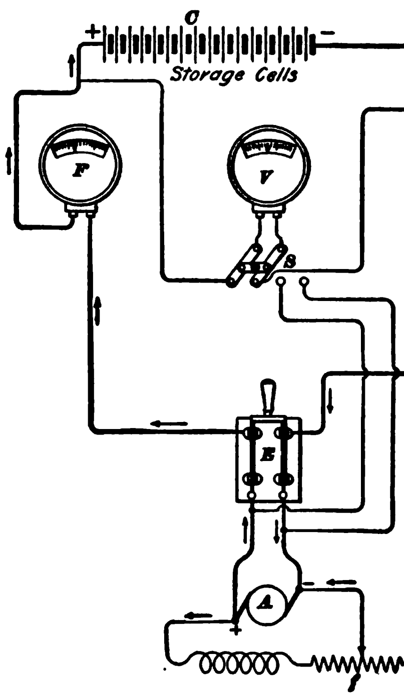


FIG. 21

dynamo; if this were not the case, a resistance would have to be inserted in series with the battery. Charging is effected as follows: Having made sure that the connections are all right, and that switch E is open, get the dynamo up to speed. Then measure the voltage of the cells and adjust the field rheostat of the dynamo until the voltage of the latter is from 5 to 10 per cent. higher than that of the

cells. Throw in the main switch and adjust the rheostat until the ammeter indicates the charging current called for by the makers of the cells.

The outfit shown in Fig. 21 is sufficient where a battery is simply to be charged and where a fairly close watch can be kept on it while the charging process is going on. Generally, however, the connections must be arranged so that the cells may be either charged from the dynamo or allowed to discharge into the line. It is also necessary to have fuses or an automatic circuit-breaker of some kind to protect the battery against overloads. An underload switch is also connected between the cells and the dynamo, as indicated by the dotted outline *K*, Fig. 21. The duty of this switch is to prevent the cells from discharging into the dynamo and running it as a motor; it is, usually, an automatic switch controlled by an electromagnet connected in series between the dynamo and the battery. If for any reason the current drops to a very low value, the electromagnet releases its armature, thus opening the switch and disconnecting the cells from the machine.

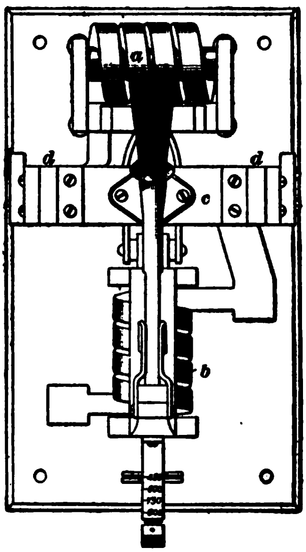


FIG. 22

50. Cutter Automatic Overload and Underload Switch.—Fig. 22 shows a special automatic switch designed to protect the dynamo from any backward rush of current and also to protect the battery from overloads. Two coils *a*, *b* are connected in series between the battery and dynamo, as indicated at *K*, Fig. 21. If the current becomes excessive, coil *b* pulls up a core that releases a trip and allows a spring to throw the arm out, thus breaking the circuit at *d*, *d*. When the battery is charging, coil *a* holds its armature, but if the

current becomes very small, as it must do before it begins to reverse and flow back from the batteries, the armature is released and causes the switch to open. The instrument is therefore a protection against both underload and overload. For example, a battery might be charging and the speed of the dynamo might drop or the belt fly off. In either case, the voltage of the dynamo would drop and the charging current fall to zero. If the circuit were not opened, a current would flow from the battery through the dynamo and run it as a motor. Another instance in which damage might result if an underload switch were not used is in case the field circuit of the dynamo should become broken. This would reduce the E. M. F. of the dynamo to zero and a large rush of current could take place through the armature, because the cells would be unable to excite the field so as to enable the machine to generate any counter E. M. F. as a motor. In the case of a compound-wound dynamo, a backward rush of current might result in a reversal of the dynamo field. In the case of a simple shunt dynamo, the current flows around the shunt in the same direction no matter whether the dynamo is charging the battery or whether the battery is forcing current back

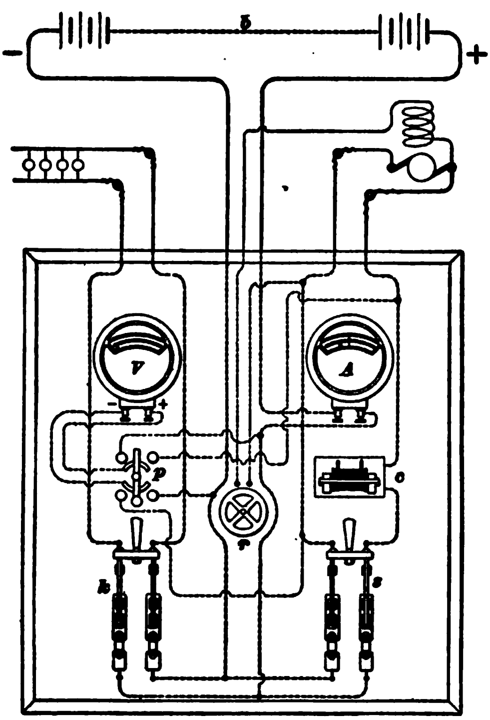


Fig. 28

through the dynamo. Fig. 23 shows a simple switchboard suitable for a small plant where a battery is used in conjunction with a dynamo for lighting or other purposes; *k* and *s* are double-pole knife switches provided with fuses, *k* controls the lighting circuit while *s* is connected to the dynamo through the underload circuit-breaker *c*. The ammeter *A* is connected in series with the battery *b* and indicates the charging or discharging current. *V* is a voltmeter connected to a switch *p*, by means of which it may be connected across either the dynamo or the battery; *r* is the handle of the field rheostat that is connected in series with the shunt field of the dynamo. When the battery is being charged, the switch *k* is open and the switch *s* closed. When the battery alone is furnishing current to the line, *s* is open and *k* closed. If it is desired to have both battery and dynamo furnish current to the line, both switches are closed.

51. In Fig. 24 is shown a **dynamotor,** or **rotary converter,** which is a dynamo and motor combined in one machine, connected across a 220-volt power or lighting circuit. It furnishes current from the generator side *y* at 10 volts, for charging storage batteries *S*, *S*, arranged in duplicate sets, four cells in series in each set. In both the 220- and 10-volt circuits there are overload and underload circuit-breakers, each adjusted to open its own circuit in case the current exceeds or falls below predetermined safe values. If the rheostat *C* is used not only to start up the machine, but also to regulate the voltage on the *y* or generator side of the machine, it must have sufficient current-carrying capacity not to become overheated and burned out by the largest current it may be called on to carry for an indefinite length of time.

Whenever the machine is shut down, whether by the intentional opening of the switch *B* or by the opening of the automatic circuit-breaker *M* in the 220-volt supply mains, the arm of the rheostat *C* should be immediately turned to the off-position. Thus, the danger of injuring the machine, generally due to carelessness by closing the switch *B* and

the circuit-breaker *M* before returning the rheostat arm to the off-position, is avoided. However, the overload device of the circuit-breaker *M* will open the circuit again as soon as *B* is closed if *C* is not returned to the off-position before an attempt is made to start the machine.

It is sometimes desirable to have an adjustable resistance or rheostat *a* in circuit with each group of cells while charging, so that the strength of the charging current may be regulated in each group independently, which is advisable in case the cells were not equally discharged.

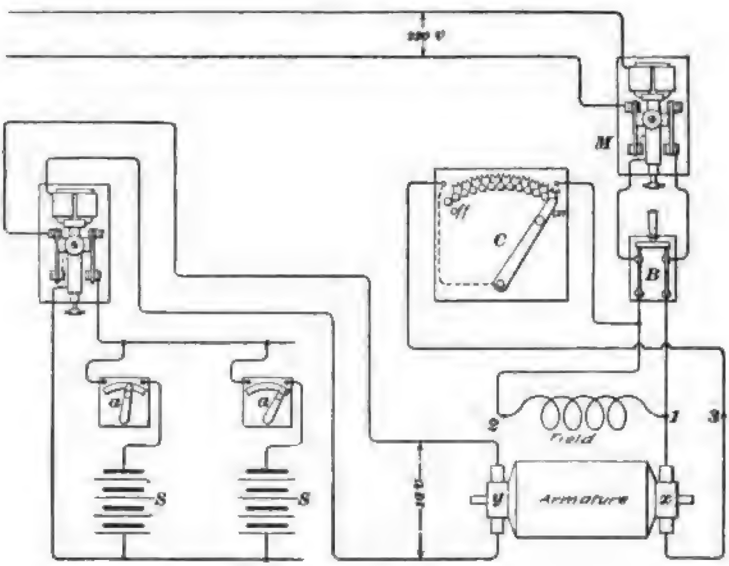


FIG. 24

52. Storage batteries may be arranged in duplicate, in order that one battery may be charging while the other is discharging. A simple arrangement of switches whereby either battery may be switched on to either the charging or discharging circuit is shown in Fig. 25, in which *B* and *B'* represent two storage batteries, each consisting of seven cells in series. *S* and *S'* are double-pole, double-throw, knife switches, the levers of which are connected, respectively, with the plus and minus poles of the batteries. The upper

pair of contacts on each switch is connected with the positive and negative mains of the charging circuit, while the lower pair is connected in a similar manner with the two sides of the discharging circuit. Both sides of each, the charging and discharging circuits, should be fused for a current slightly in excess of the maximum charge or discharge rate of the battery, and of course the wires in each of these circuits should be made of ample capacity for carrying these currents without undue heating.

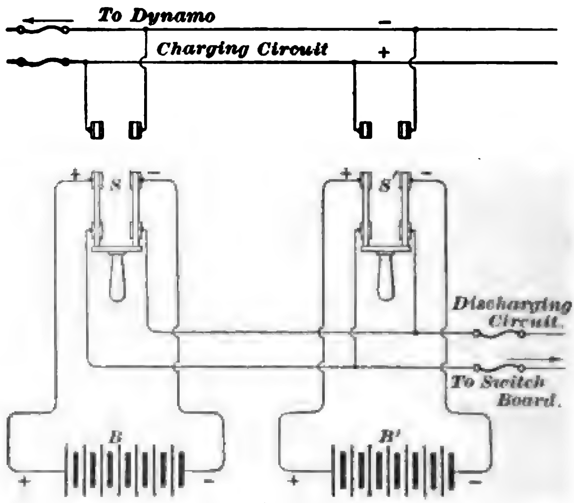


FIG. 25

53. Charging While in Use.—If storage batteries are being charged while in use, it frequently happens that a hum is produced in all the receivers in use. This hum may be due to the fact that the current generated by the dynamo decreases and increases somewhat in strength each time the dynamo brush passes from one commutator bar to the next. It may also be due to the fact that the armature wires are wound in slots that, together with the pole tips, are not properly designed to give a smooth current. In either case, the current fluctuates in strength sufficiently to affect all the telephones that are being supplied with current while the battery and dynamo are in parallel.

The intensity of the hum may be reduced by connecting, as shown in Fig. 26, a condenser *C* and impedance coils *R*, *R'* in the circuit of the charging dynamo. The impedance coils tend to choke back the increasing current and the condenser to absorb the extra current, which it gives up again when

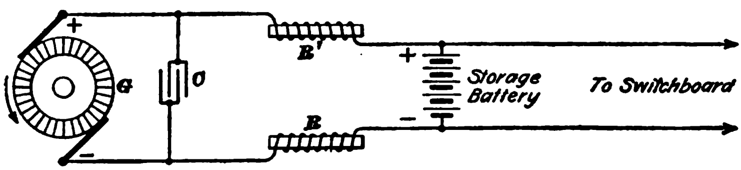


FIG. 26

the current in the dynamo circuit decreases; thus the current that reaches the storage battery fluctuates much less in strength with, than without, the condenser and impedance coils.

These impedance coils may be made as follows: each coil consists of twenty turns of No. 4 B. & S. copper wire wound on a straight core of iron wire 8 or 10 inches long.

54. Charging machines may now be obtained that are so designed and built as to produce no humming noise when the brushes and commutator are in good condition. The rate at which the commutator bars pass under the brushes should be several thousand per second and the commutator must be composed of a large number of long narrow segments; the brushes must fit it closely and have no perceptible vibration. The armature and field must be liberally proportioned.

It has been found possible, with proper precautions, to operate directly from the generator without the intervention of storage batteries and without the slightest disturbance on the lines. While it would not be advisable to attempt to get along without a storage battery, it is well to know that in case of a disaster to the battery the exchange can still operate until the necessary repairs are made.

For 5 or 6 years the Holtzer-Cabot Electric Company claims to have been making a line of dynamos designed to generate current sufficiently smooth and noiseless to be used directly

on transmitter circuits. The construction of these dynamos is such that all noises are practically eliminated. A choke coil is connected between the machine and the transmitter circuits to further smooth out the undulation of the current, making it approach very near an absolutely continuous current such as that given by a battery. By this arrangement current may be secured from a dynamo that is almost as quiet as that given by a storage battery. Such a dynamo may be used to charge storage batteries at the same time that the latter are supplying the switchboard with current, or may, in case of disability of the batteries, be used to supply current directly to the transmitter and line circuits.

CHARGING EQUIPMENT

55. There are two methods in common use for charging storage batteries in telephone exchanges: First, charging directly from direct-current electric-light or power mains through an adjustable resistance in series with the battery. Second, charging by means of a generator, which may be directly connected to a motor, operating on commercial circuits, or driven by a gas engine, water turbine, or a convenient shaft. A third method, which is coming into use where the street mains supply alternating current, is by the use of the mercury-vapor converter, which is described elsewhere.

By the first method it is necessary to connect a dead resistance in series with the charging circuit. As commercial electrical circuits are very seldom lower than 110 volts, a large percentage of energy is wasted in the dead resistance as it is usually necessary to reduce the potential across the battery to at least 45 volts. The efficiency of this arrangement is the ratio of the voltage across the battery terminals while charging to the full voltage across the charging mains. Charging a 20-cell battery, requiring 45 volts to charge it, from a 110-volt circuit gives an approximate efficiency of $45 \div 110 = 40.9$ per cent.; from a 220-volt circuit gives an efficiency of 20.4 per cent. This is an exceedingly uneconomical way of obtaining power and is seldom used except for

very small batteries. However, by the use of 80-volt lamps, the lighting of the exchange can sometimes be done with the same lamps that are used as a resistance in charging; the loss of efficiency is not then very large.

56. The second method, involving the use of a generator, is very extensively used as it is more economical, more flexible, and more satisfactory in all respects when properly installed. Of the different methods of driving the generator, the direct-connected motor is the most common and probably the most satisfactory. The electrical efficiency of motor-generators, that is, the percentage of watt output to watt input, varies from 46 to about 73 per cent. according to the size and construction of the machines.

The size of the motor generator must be such that the generator will have sufficient output to charge the storage battery of the ultimate capacity within the time limit, if there be one; 8 hours is generally taken. The charging machine used, then, should be sufficiently large to deliver current equaling the ultimate charging rate of the battery, which rate is determined and supplied by the manufacturer of the battery, at a voltage from 20 to 30 per cent. in excess of the total voltage of the battery when fully charged.

Where there is only one battery, so that the generator has to carry the switchboard load and charge at the same time, its capacity should equal the normal rate of the battery plus the average switchboard load during the charging period. Where there are two batteries, it need only be large enough to carry the normal charging rate.

Charging sets should always be installed in duplicate and the motors wound for separate primary circuits leading in from different central stations where possible, otherwise it is well to install a gas engine or turbine and an engine-type generator. Spare armatures are advisable.

BEST TIME TO CHARGE

57. Although some advocate the installation of duplicate storage batteries to avoid any possible interruption in the service, this practice is not now considered necessary, except where required for other purposes than reliability. Furthermore, one battery is better than two from the standpoint of efficiency. It is most efficient to charge the battery during the busiest part of the day, not at night.

The exchange should operate on the battery alone only when the load falls to that point where the motor generator operates at 52 per cent. efficiency or less—that is about one-third full-load current. By charging during the busy hours, the motor generator may be operated at its most efficient load and the batteries may be charged and discharged at the most efficient rate—i. e., at the normal rate or less.

The practice of charging the batteries constantly, or floating them, as it is called, is an economical one, as current is being delivered direct to the switchboard from the motor generator and at the same time the battery is charging at a slow rate. Even plain lead plates in battery solution will answer if they can be charged continuously or in an emergency.

SIZE OF BATTERY REQUIRED

58. The only way to arrive at an intelligent conclusion regarding the size of battery to be used for any given case is to determine, as nearly as possible, the ampere-hours and voltage required. As the output of most plants is always increasing, it is common practice to install jars or tanks somewhat larger than required at the start. The capacity of the cells can then be easily increased by simply adding more pairs of plates to each cell.

The number of cells required for a given installation will depend on the voltage of the system, and also, in some cases, on the range of voltage regulation that is desired by cutting cells in or out. Assuming that the cells are discharged down to 1.75 volts, the minimum number of cells required will be

the voltage of the system divided by 1.75. For example, a battery for a 110-volt system will require 110 ÷ 1.75 = 63 cells. However, the number of cells required in a battery for operating telephone systems is usually taken as one-half the voltage; for instance, twenty cells are used for a 40-volt battery. There are several standard voltages in use at the present time, namely 20, 24, 36, 40, and 48.

59. The higher voltage systems present certain advantages, owing to the fact that to convey equivalent amounts of energy but one-half the current is required at 40 volts as at 20. The advantage on long lines is obvious. If the current strength is halved on lines of any length, induction and cross-talk are correspondingly diminished; while by winding repeating or induction coils to a higher resistance, the required amount of induction may be obtained where it is a desirable quality. Another point in favor of the higher voltage is that transmitters may be made higher in resistance, thus increasing the percentage of the varying talking resistance to the total resistance of the line, and on this percentage good transmission largely depends.

QUANTITY OF BATTERY CURRENT REQUIRED TO OPERATE CENTRAL-ENERGY CIRCUITS

60. It is not possible to devise any formula by which to determine the size of the storage battery to install, from the number of subscribers to be served or the size of the exchange, for the reason that conditions vary so greatly, even in telephone systems of the same number of subscribers. In fact, exchanges of the same size and using the same system, may require power plants of much different capacities, by reason of the difference in the amount of business to be handled. In determining the size of the individual cells, it is not sufficient to provide for present needs, but provision should be made to take care of the probable growth. It is customary, therefore, to provide lead-lined tanks or glass jars of sufficient capacity to contain the elements required to operate the ultimate capacity of the switchboard and to equip those tanks

with elements of sufficient capacity to slightly exceed the load imposed by the present equipment.

61. One condition on which depends the size of the cells is the load or discharge rate. This depends not only on the size of the exchange, but on the business and social activity of the city wherein the plant is located; on the outside-line construction; and on the electrical design of the system. A few figures, which may be of value as a general guide, will now be given. The amount of current required for each subscriber's transmitter is from .05 to .1 ampere; the average length of conversation is about 3 minutes, and the average number of connections each subscriber makes in a day is from five to fifteen. The amount of current required by the operator's transmitter is about .12 ampere, which should be considered as being used continuously throughout the day. Then there is the current required for the lamps, which, counting line and supervisory, is about .06 ampere, the duration being about 6 seconds for each call. If cut-off relays are used, they are in circuit for about 3 minutes each call, and the current they require should be figured at about .05 ampere. The pilot lamps, either one or two for each operator, can be figured on as drawing current about 7 hours a day. These take about the same amount of current as a line lamp, .06 ampere. From these figures, it will be possible to arrive with some degree of accuracy at the number of ampere-hours that will be used in a day's work. The current required for a conversation runs from .08 to .4 ampere in the different systems. Assuming roughly as average conditions twelve calls of 3 minutes' duration taking .1 ampere each, would give $12 \times \frac{3}{60} \times .1 = .06$ ampere-hours as necessary per subscriber.

62. Another condition is the number of hours that the battery must be capable of carrying the load on a single charge. This depends, in turn, on the number of hours of the 24 during which charging current is available, for it is often the case, especially in smaller cities, that light and power companies offer certain reductions to consumers using

current during light-load hours, while in some localities no day current is supplied. Local conditions are, therefore, an important factor. The minimum permissible battery capacity is that which would be obtained by allowing for an 8-hour charge at the normal rate of the battery out of each 24 hours.

It is perhaps wiser, especially in the smaller exchanges, to install a battery large enough to carry the load for 36 hours, or even 48 hours, on a single charge, depending on the reliability of the charging source. If two batteries are installed, one should be charged while the other is discharging, in order that the batteries may be worked up near the point of greatest efficiency; that is, between three-fourths charge and full charge, as the lower and upper limits, respectively, and at the same time insure continuous operation. The efficiency of storage batteries averages between 75 and 80 per cent. in telephone work.

63. An idea of the size of batteries used in telephone exchanges may be obtained from the following examples: In a Bell exchange in Chicago having 4,300 subscribers, a storage battery is used having a capacity of 1,920 ampere-hours and a normal discharge rate of 240 amperes at 24 volts. In another Bell exchange, a 2,000-ampere-hour, 24-volt battery was installed to care for 5,000 lines. The Kellogg exchange installed in the Pan-American Exposition had about 950 lines and a storage battery of 240 ampere-hours capacity at 20 volts. In the Rochester exchange, the Stromberg-Carlson Company installed a 40-volt storage battery having a capacity of 360 ampere-hours for 3,600 subscribers. Soon after starting this exchange, the total current did not exceed 15 amperes, or 600 watts, for talking and ringing purposes.

64. Insulation of Cells.—Battery jars and tanks should be carefully insulated from each other and from the ground, as bad leaks quite frequently occur from faulty erection work and carelessness. A leak from the lead lining of a wooden tank, or from the all-metal tank to ground, or from tank to

tank, is not only a source of loss of energy, but incurs grave dangers from electrolytic actions.

The lead lining of a cell shows a definite potential difference to the positive and negative elements within the tanks, when the cell is properly insulated, the sum of the potentials being equal to the voltage of the cell. On full charge when the voltage of the cell stands at 2.1 volts, the lead lining of the cell should be 1.4 volts negative to the positive plates and .7 volt positive to the negative plates. When the voltage of the cell has dropped to 2 volts the lining should be 1.35 volts negative to the positive plates and .65 volt positive to the negative plates. If grounded, the lead lining will be at the same potential as the positive plates of the tank, which are usually grounded in telephone systems. This is an accurate method of testing for grounded tanks.

Beginning at the grounded end of a storage battery, each succeeding cell adds 2.1 volts to the potential above ground. Hence as the lead lining of the first tank stands at 1.4 volts above ground potential, the second cell will stand at 3.5, volts, the third at 5.6 volts, the fourth at 7.7 volts, and so on to the twentieth at 37.2 volts above ground.

Grounding any one of the metal-tank linings will cause a current to flow to earth, the voltage almost immediately dropping to the potential of the positive plates in the cell. Should the cell be left grounded, the metal will be eaten through by the formation of peroxide. After removing the ground, the potentials between metal lining and plates rapidly assume the normal; 15 or 20 minutes should be sufficient for complete recovery. In case of a cross between two tanks, current will flow from the tank of higher potential to the lower through the connection, and from the lead lining of the latter through the solution to the negative plates, and the lead lining of the latter cell will therefore be destroyed by electrolysis.

BATTERIES FOR OPERATORS' TRANSMITTERS

65. Individual-Transmitter Batteries.—In exchanges not using the common-battery systems for supplying current from a central source to all the subscribers' stations, several methods may be used for supplying current to the operators' transmitters at the central office. One of these, frequently used in small exchanges, is to make each operator's primary circuit entirely separate from all the others, and include in it about three gravity cells in series. This arrangement gives only fair results, and sometimes requires the maintenance of quite a large number of gravity cells. These cells are at best not well adapted for telephone purposes, on account of their high internal resistance. The internal resistance can be reduced by connecting two or more sets of three in parallel, requiring, of course, more cells.

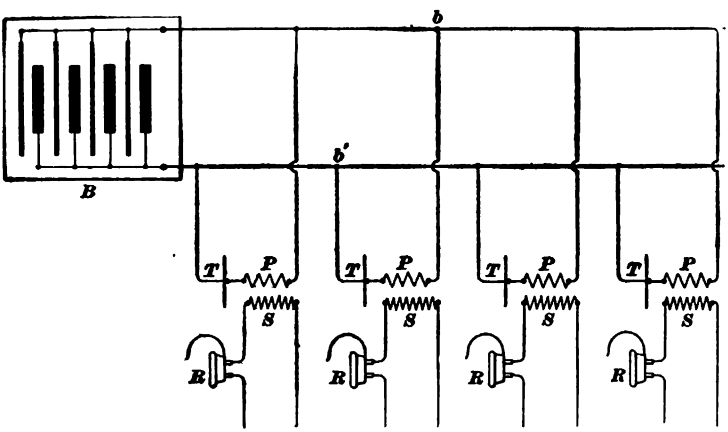


FIG. 27

66. Transmitter Circuits in Multiple.—The ordinary practice of many companies is to connect all the operators' transmitter circuits in multiple with the bus-bars leading from a storage battery. This arrangement is shown in Fig. 27, in which B is the storage battery, b and b' the bus-bars, T the transmitters, and P the primary coils of the various operators' circuits. The operators' receivers R and

the secondary coils S are associated with the primary circuits in the ordinary way. Such an arrangement, if properly installed, will not produce cross-talk between the operators' circuits, and in order to bring about this desirable condition, two points must be considered: the first of these is that the storage battery shall be of extremely low internal resistance; and the second is that the bus-bars shall be very short and of such a thickness as to render their resistance negligible. The reason for this is that if the resistance from the point on one bus-bar where the transmitter circuits join it, through the battery and to the corresponding point on the other bus-bar, is not very low, the difference of potential at these points b, b' will vary in unison with the current in that transmitter circuit, and, consequently, the current in another transmitter circuit will vary in turn with this difference of potential, causing, therefore, cross-talk in the second circuit. On the other hand, if the battery and the bus-bars are of sufficiently low resistance, the difference of potential between b, b' will vary by an inappreciable amount, causing, therefore, inappreciable cross-talk in the second circuit. To further explain this, suppose that the total resistance of the bus-wires from b, b' to the battery and the internal resistance of the battery to be high, say 2 ohms, and the maximum and minimum current in the bus-bar, caused by the change in resistance in the one transmitter circuit connected to points b, b', to be 1 and .999 ampere, respectively, the change in potential at the points b, b' will be

$$2 \times 1 - 2 \times .999 = .002 \text{ volt}$$

Now, suppose that bus-wires so much larger are used that the total resistance is only .006 ohm, the change in potential will be

$$.006 \times 1 - .006 \times .999 = .000006 \text{ volt}$$

or only $\frac{3}{1000}$ as great a fluctuation in the voltage at the terminals of the transmitter circuit as before. Consequently, the fluctuating currents, and therefore the cross-talk, in another transmitter circuit will be only $\frac{3}{1000}$ as great in this case as in the first. In installing this system in exchanges of medium size, a storage battery of a capacity of at least

100 ampere-hours should be used, and the bus-bars made of 000 trolley wire, not over 18 inches in length. Such a construction will give complete freedom from cross-talk, while with the same battery and the same number of transmitter circuits, bus-bars 6 feet long, of No. 3 wire, would cause much troublesome cross-talk.

BOOSTER BATTERIES

FOR LONG LINES

67. In telephone systems, storage or primary batteries, may be arranged to boost the voltage applied to a circuit for two purposes. A battery common to all lines in an exchange should furnish the longest line with enough current without giving the shortest line too much current. Although this may be satisfactorily accomplished for local conversations, the longest local lines may not get enough current for the best efficiency when talking over long-distance lines. This difficulty is reduced by the arrangement shown in Fig. 28.

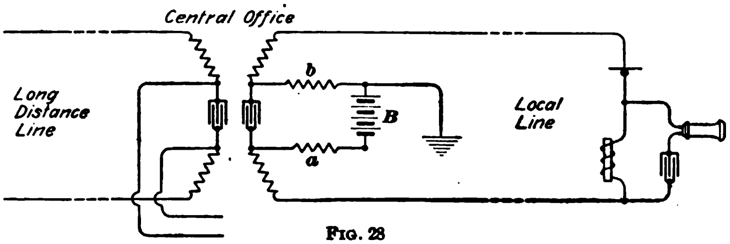


FIG. 28

This circuit is intended to supply current for a trunk circuit between long-distance and local lines and the battery B has a voltage of, say, 48 or twice that used for local conversations in a Bell system. The resistances a, b are adjusted to give enough current to the shortest local lines, while the battery without any unnecessary resistance in its circuit gives quite a little more current than under standard conditions to the long-distance line across which it may be directly connected.

TO OVERCOME GROUND POTENTIAL

68. Sometimes, the ground potential in two exchanges may vary as much as 16 volts on account of stray electric-railway currents and cause considerable trouble in the operation of trunk or toll circuits between the two exchanges. If

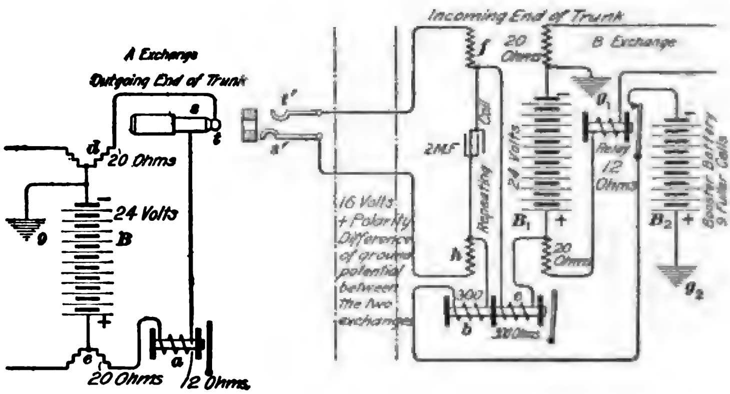


FIG. 29

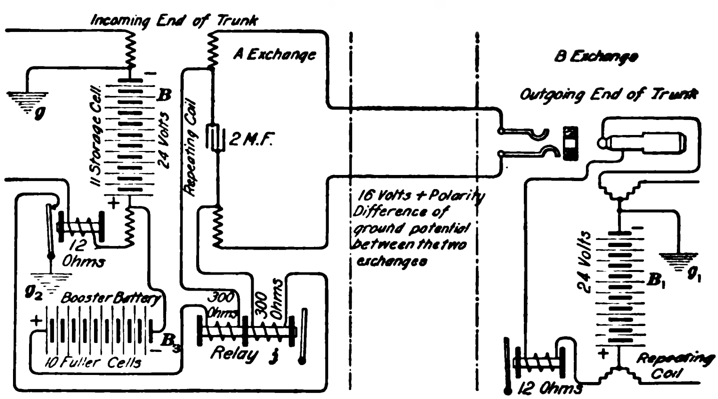


FIG. 30

the ground at one exchange is 16 volts above the ground at another exchange, one side of the trunk circuit will have a potential difference between its ends equal to the voltage of the exchange storage battery plus 16 volts, say 24 + 16 = 40 volts, enough to operate the relays, while the other

side will possess only $24 - 16 = 8$ volts, not enough to operate the relays. To remedy this trouble, extra batteries, called **booster batteries** are sometimes used.

Figs. 29 and 30 show the connections of both ends of one-way or circuit trunks from one central-energy exchange to another. There is an earth potential of about 16 volts tending to send current from the ground at the B exchange to the ground at the A exchange. To overcome this, the terminals of the regular batteries B, B_1 are connected as shown and extra booster batteries, B_2 in Fig. 29 and B_3 in Fig. 30, composed of a suitable number of Fuller bichromate primary cells, are connected in the circuit with their positive terminals toward the ground at the B exchange in order to oppose the potential due to the earth at this exchange. The trunk shown in Fig. 29 is used for completing connections in one direction, while that shown in Fig. 30 is used in the opposite direction. Although not shown, order-wire circuits are, of course, necessary.

In Fig. 29, the tip side may be traced through g–d–t–t'–f–c–B_1–g_1. The potential due to the earth assists B_1, so that the booster battery is not required in this part of the circuit. The sleeve side may be traced through g–B–e–a–s–s'–h–b–B_2–g_2. B_2 opposes and equalizes the earth potential acting in this circuit, leaving B to act alone and generate enough current to operate the relays in this circuit.

In a similar manner, it may be shown that B_3 in Fig. 30 equalizes the earth potential in the tip side of the trunk circuit in which the earth potential would otherwise weaken the current produced by the regular battery B; while the booster battery B_3 is not included in the sleeve side in which it is not needed. These trunk circuits resemble so closely those shown and fully explained in *Bell Trunk Circuits*, that it seems unnecessary to further explain them here.

GENERAL DATA ON STORAGE CELLS

69. In order to give an idea as to the size, capacity, weight, etc. of storage cells, Tables I, II, and III are here given. These tables do not show all the sizes of each type because cells can be made up with almost any number of plates desired. In each table, the first cell of a given type is the smallest size made in that type and the last given is the largest. The number of plates per cell is always an odd number because there is always one less plate in the group of positives than in the group of negatives. For example, a 13-plate cell would be made up of six positives and seven negatives. The capacities of cells with a number of plates different from that shown in the tables can be easily calculated. For example, in Table I, the 9-plate, type F cell has an 8-hour capacity of 40 amperes and a 15-plate cell of the same type has a capacity of 70 amperes. The addition of six plates or three pair of plates increases the capacity 30 amperes; hence, the capacity per pair of plates is 10 amperes. A 27-plate cell has thirteen pair; hence, its capacity is $13 \times 10 = 130$ amperes for 8 hours. In making estimates of the room occupied by a given battery, about $1\frac{7}{8}$ inches clearance should be allowed between glass jars, $2\frac{3}{4}$ inches between metal tanks, and 2 inches between wooden tanks.

TABLE I

GENERAL DATA ON CHLORIDE ACCUMULATORS

Type of Cell	Size of Plates Inches	Number of Plates	Normal Charge Rate Amperes	8-Hour Discharge Rate	Weight of Cell Complete With Acid, Glass Jar Pounds	Weight of Cell Complete With Acid, Metal Tank Pounds	Weight of Cell Complete, Lead-Lined Tank Pounds	Dimensions of Glass Jars Inches			Dimensions of Lead-Lined Tanks Inches		
								Width	Length	Height	Width	Length	Height
C	4⅜ × 4	3	1¼	1¼	6½ (rubber jar)			3½	5¼	7¼			
C	4⅜ × 4	5	2½	2½	10 (rubber jar)			4¼	5¼	7¼			
C	4⅜ × 4	7	3¾	3¾	13 (rubber jar)			5¼	5¼	7¼			
D	6 × 6	3	2½	2½	20			3¼	7⅞	9½			
D	6 × 6	5	5	5	28			4¾	7⅞	9½			
D	6 × 6	7	7½	7½	38			6⅛	7⅞	9½			
D	6 × 6	13	15	15	63			11	8¼	9½			
E	7¾ × 7¾	5	10	10	49	85		5½	9⅝	11⅝			
E	7¾ × 7¾	9	20	20	75	125		8	9⅝	11⅝			
E	7¾ × 7¾	15	35	35	115	183		11	9⅝	11⅝			
F	11 × 10½	9	40	40	163	239	250	9	12⅝	15½	13⅜	15	20¼
F	11 × 10½	15	70	70	246	352	372	12	12⅝	15½	18⅝	15	20¼
F	11 × 10½	27	130	130		581	615				28⅝	15	20¼
G	15½ × 15½	11	100	100			561				15⅛	19¾	26
G	15½ × 15½	25	240	240			1,156				27⅝	20¾	26⅛
G	15½ × 15½	55	540	540			2,434				53¼	21½	27⅞
G	15½ × 15½	75	740	740			3,260				69⅞	21½	27⅞
H	15½ × 30¾	21	400	400			1,885				25⅛	21½	48¾
H	15½ × 30¾	41	800	800			3,408				41⅝	21½	49¾
H	15½ × 30¾	75	1,480	1,480			5,986				69⅞	21½	49¾

TABLE II

GENERAL DATA ON GOULD STORAGE CELLS

Type of Cell	Size of Plates Inches	Number of Plates	Normal Charge Rate Amperes	8-Hour Discharge Rate Amperes	Weight of Cell Complete With Acid, Rubber Jar Pounds	Weight of Cell Complete With Acid, Lead-Lined Tank Pounds	Dimensions of Rubber Jar Inches			Dimensions of Glass Jar Inches			Dimensions of Lead-Lined Tank Inches		
							Width	Length	Height	Width	Length	Height	Width	Length	Height
K	3 × 3	3	.75	.63	4.3		2 1/4	3 3/4	5 1/2	3 1/4	4 3/4	5 3/4			
K	3 × 3	5	1.5	1.25	7.7		3 7/8	3 3/4	5 1/2	4 7/8	4 3/4	5 3/4			
L	4 × 4	3	1.5	1.25	6.6		2 1/4	4 3/4	6 1/2	3 1/4	5 3/4	6 3/4			
L	4 × 4	7	4.5	3.75	16.6		5 1/2	4 3/4	6 1/2	6 1/2	5 3/4	6 3/4			
M	6 × 6	3	3	2.5	12.8		2 3/8	6 3/4	8 1/2	3 3/8	7 3/4	9 1/2			
M	6 × 6	7	9	7.5	31.2		5 5/8	6 3/4	8 1/2	6 3/4	7 3/4	9 1/2			
M	6 × 6	11	15	12.5	49.9		8 7/8	6 3/4	8 1/2	10	7 3/4	9 1/2			
N	7 3/4 × 7 3/4	5	10	10	34.3		4	8 1/2	10 1/2	5 1/8	9 1/2	11 1/4			
N	7 3/4 × 7 3/4	9	20	20	64.9		7 1/4	8 1/2	10 1/2	8 3/8	9 1/2	11 1/4			
N	7 3/4 × 7 3/4	13	30	30	95.5		10 1/2	8 1/2	10 1/2	11 5/8	9 1/2	11 1/4			
O	10 1/2 × 10 1/2	5	20	20						5 5/8	12 1/4	15			
O	10 1/2 × 10 1/2	11	50	50		220							11 1/2	15	18
O	10 1/2 × 10 1/2	17	80	80		328							16 3/4	15	18
S	15 1/2 × 15 1/2	5	40	40		237							6 1/4	20 3/8	27 3/8
S	15 1/2 × 15 1/2	19	180	180		839							20	20 5/8	27 5/8
S	15 1/2 × 15 1/2	35	340	340		1,527							35 3/4	21 1/8	27 5/8
S	15 1/2 × 15 1/2	67	660	660		2,903							67 3/4	21 7/8	27 7/8
T	15 1/2 × 31	11	200	200		870							13	21 3/8	45 7/8
T	15 1/2 × 31	53	1,040	1,040		4,064							55 5/8	22 5/8	46 5/8
T	15 1/2 × 31	105	2,080	2,080		8,066							108	23 5/8	46 7/8

TABLE III

GENERAL DATA ON ELECTRIC VEHICLE CELLS

Type of Cell	Size of Plates Inches	Number of Plates	Discharge for 4 Hours Amperes	Weight of Cell Complete With Acid Pounds	Dimensions of Hard-Rubber Jar Inches		
					Width	Length	Height
Exide M V	$5\frac{3}{4} \times 8\frac{5}{8}$	7	21	$19\frac{1}{2}$	$2\frac{7}{16}$	$6\frac{3}{16}$	$11\frac{1}{2}$
Exide M V	$5\frac{3}{4} \times 8\frac{5}{8}$	9	28	26	$3\frac{1}{4}$	$6\frac{3}{16}$	$11\frac{1}{2}$
Exide M V	$5\frac{3}{4} \times 8\frac{5}{8}$	11	35	32	$4\frac{1}{4}$	$6\frac{3}{16}$	$11\frac{1}{2}$
Exide M V	$5\frac{3}{4} \times 8\frac{5}{8}$	15	49	$44\frac{1}{2}$	$5\frac{3}{16}$	$6\frac{3}{16}$	$11\frac{1}{2}$
Exide M V	$5\frac{3}{4} \times 8\frac{5}{8}$	19	63	$56\frac{1}{2}$	$7\frac{3}{16}$	$6\frac{1}{4}$	$11\frac{9}{16}$
Exide P V	$4\frac{13}{16} \times 8\frac{5}{8}$	5	12	12	$1\frac{13}{16}$	$5\frac{5}{16}$	$11\frac{1}{2}$
Exide P V	$4\frac{13}{16} \times 8\frac{5}{8}$	7	18	$17\frac{1}{2}$	$2\frac{9}{16}$	$5\frac{5}{16}$	$11\frac{1}{2}$
Exide P V	$4\frac{13}{16} \times 8\frac{5}{8}$	11	30	$27\frac{1}{2}$	$4\frac{1}{4}$	$5\frac{5}{16}$	$11\frac{1}{2}$
Gould E V	$5\frac{7}{8} \times 9$	5	17	$20\frac{1}{4}$	$2\frac{1}{2}$	$6\frac{1}{4}$	$11\frac{1}{2}$
Gould E V	$5\frac{7}{8} \times 9$	9	33	37	$4\frac{1}{4}$	$6\frac{1}{4}$	$11\frac{1}{2}$
Gould E V	$5\frac{7}{8} \times 9$	15	$57\frac{1}{2}$	$59\frac{1}{2}$	$7\frac{1}{4}$	$6\frac{1}{4}$	$11\frac{1}{2}$

INDEX

NOTE.—All items in this index refer first to the section and then to the page of the section. Thus, "Bends in hand-made cables, §27, p7," means that bends in hand-made cables will be found on page 7 of section 27.

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